AGRICULTURE
FOR
SCHOOLS.

LOVELL'S SERIES OF SCHOOL BOOKS.

FIRST LESSONS

IN

SCIENTIFIC AGRICULTURE.

FOR SCHOOLS

AND

PRIVATE INSTRUCTION.

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PREFACE.

The writer of this little book had, in his youth, some opportunities of becoming familiar with agricultural operations; and read with eagerness and enthusiasm those remarkable works of Liebig and Johnston, which in 1840 and the following years revived throughout Britain and America the interest in the applications of chemistry to agriculture which had been awakened by Sir Humphrey Davy. It was subsequently his duty, as Superintendent of Education in Nova Scotia, to make an effort to introduce the teaching of agricultural chemistry into the schools of that Province; and more recently it has fallen to him to communicate some knowledge of the subject to the teachers in training in the McGill Normal School in Montreal.

From these labors has grown the present work, which is intended as a text-book for teachers desirous of introducing the study of Scientific Agriculture into their schools, and also as a manual for young men who may be pursuing the subject as a branch of private study. It is designed to place before such persons the facts and principles which the experience of the writer has

shown to be most important in relation to the existing state of agriculture in British America.

The writer has ventured to deviate from the plan of ordinary school text-books, and to throw the matter into the form of a series of reading lessons adapted to the use of a senior class. It is proposed that the pupils shall, either in school or at home, read a few pages daily, or as often as may be convenient, and shall then answer questions thereon, and receive such further information as the teacher may be able to give. In this way any intelligent pupil may so master the elements of the subject as to be able to reduce its principles to practice in farming operations, and to enter with advantage on the study of larger works.

It is to be observed that this work is strictly elementary. It makes no pretension to completeness, either in chemical science or practical agriculture. It is not intended to finish the studies of the pupil on this subject, but to render them more easy and profitable; and the writer would advise both the teacher and the practical farmer desirous of obtaining a more full acquaintance with the subject, to add to their libraries as many as possible of the larger agricultural books, of which so many are now accessible.

The writer acknowledges with thanks his obligations to Dr. T. Sterry Hunt, Professor of Applied Chemistry in McGill University, and to Prof. Robins of the McGill Normal School, for many valuable suggestions and corrections.

McGill College, 2nd January, 1864.

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FIRST LESSONS

IN

SCIENTIFIC AGRICULTURE.

CHAPTER I.

THE SCIENCE OF AGRICULTURE AND ITS USES.

§1. *Nature of the subject.*

In our time all useful arts are more or less closely connected with scientific facts and principles, and it is to this connection that these arts mainly owe their present high perfection and progressive improvement. The votary of abstract science may in his researches regard only the laws of nature, without reference to the arts of life; yet his discoveries necessarily bear on those arts, since the laws of nature are those under which the artisan, or the farmer, must work. They surround him on every side. They have fixed the properties of all the things he uses for his purposes, and have determined the steps of every process which can be successful.

It is the business of physical science carefully to explore nature, to ascertain the properties of every object, the laws which regulate every change and process, the conditions, in short, of existence and of action which the Creator has imposed on the things which He has made. Such knowledge must be eminently practical: it is truly power, inasmuch as it brings to bear upon matter that which is the grand agent of our mastery over it—enlightened thought. All the great forces of nature—heat, electricity, light, the various laws and properties of solids, of liquids, and of gases, and of the different kinds of matter—have been searched out by scientific investigation, and broken in and

harnessed for the use of the practical man; and every day new uses of substances, improvements of processes, adaptations of machines, are being carried out; while every new fact or principle utilised brings in its train the uses of others.

All this applies eminently to Agriculture. The farmer is not a mere manual laborer. He has to do with soils of complex composition, liable to ruinous deterioration and susceptible of great improvement. He has to tend and rear vegetable and animal organisms of complicated and varied structures and habits. He is brought in every part of his work directly into contact with nature and its laws. He is, in short, the true alchemist, whose task it is to bring out of the earth, and of things cast aside as worthless by other artists, that most valuable of all products—human food. His skill and knowledge make of the desert a fruitful field; his ignorance and carelessness may reduce the most fertile fields to desolation. Above all, the farmer is an independent workman. Isolated on his farm, he has to judge for himself in many cases of doubt,—has to plan his own processes, and to adapt them to his own circumstances. In older countries, farming, like great manufactures, may have its planning done by a few heads, while the details may be carried out by hands skilled only in a few mechanical movements; but the independent small farmers of a country like this must have the intelligence to manage as well as the skill to work.

None of the arts have derived greater benefits from science, and especially from chemistry, than agriculture. Soils, manures, and plants have been analyzed; the causes of fertility and barrenness, of running out and impoverishment, the means of supply of the most valuable constituents of crops, the enemies and diseases of cultivated plants, and many similar subjects, have been thoroughly investigated; and the result has been that agriculture has become a scientific art, and has been brought to a pitch of profitable perfection that our grandfathers would have deemed chimerical. But knowledge of this kind is yet only partially diffused. While in some countries, by the

application of scientific knowledge, land that has been cultivated for ages is being brought back to its original fertility, and its produce vastly increased; in others, through neglect or ignorance, the most fertile regions are gradually becoming unproductive.

In our own country there can be no question that much has to be learned in this respect. The history of many, if not of most Canadian farms, is that of deterioration by exhaustive cropping—a process which, if not checked by agricultural improvement, leads to failure of crops, to poverty, to discontent, and to emigration of the farming population to other countries. Every one feels that to effect a change in this, the mind of the farmer must be reached in order that his practice may be improved. But that this may be effectually done, the rudiments of agricultural science must be taught to youth; and the question for the educator is—How, and to what extent, can this be done?

We must in this carefully avoid encouraging delusive hopes, or professing to do that which we cannot satisfactorily accomplish. We cannot, in the ordinary schools, train practical chemists or practical farmers. Practical chemistry is a profession to be studied by itself, and requires a long and careful apprenticeship for its successful pursuit. The practical labor of the farmer can be learned only on a farm. The teacher must propose to himself the more humble task of instilling into the minds of the young the rudiments of the science of farming, and thereby preparing them better to understand its practical processes.—Let us inquire what he may do in this way:

§2. *What may be taught by the school teacher.*

1. He may teach of the *Soil;* of its derivation from the rocks of the earth; of its wonderful and complex composition; of its action on manures, in retaining them within it, and parting with them to the roots of plants; of the causes of its fertility and barrenness; of its impoverishment by cropping; of its improvement by tillage, by

draining, and by the application of various substances to it. He may enter into the reasons of all these, and their bearing on the practical work of the farmer, on his successes, and on his failures; and may show how the latter might often be avoided by a proper understanding of the causes which lead to them.

2. He may teach of the *Plant;* of the elements of which it is composed; of the sources, in the earth, the air, and manures, whence these are derived; of the kinds and proportions of food required by different plants, and the best means of supplying them; of the wonderful structure of the vegetable fabric, and the manner in which it forms, from the materials on which it subsists, the various products which it affords. On these subjects the discoveries of chemistry and physiology enable us to speak with much confidence as to the requirements of each crop, and its relations to the soil, to the air, and to manures, as to the uses of rotation of crops, and of special manures, and as to the causes of deficient produce, with many other important points, which, but for such knowledge, would be involved in doubt and darkness.

3. He may teach of *Manures;*—a subject hardly less interesting than the previous topics, and quite as useful. Here we have to consider the decay of dead vegetable and animal matter, and its resolution into food for plants; the losses to which the richer organic manures are liable; the nature and uses of mineral manures, with their various effects, whether directly as food for plants, or indirectly through the chemical changes which they induce in the soil. No subject has in our day more engaged the attention of chemists, and in none have more important discoveries been made.

4. He may teach of the several *Cultivated Crops* in detail, noticing their history, their modes of culture, their preferences in relation to soil, treatment, and manure; their produce—its uses to man and animals—and their enemies and diseases. He may, in like manner, proceed to apply the principles learned under these heads to the various modes of tillage, manuring and rotation, and to the treat-

ment and feeding of domestic animals. In this more practical department, the amount of instruction need be limited only by the knowledge of the teacher and the time at his command.

All these topics lie at the very threshold of agricultural knowledge and practice. They may be pursued to any extent, and the highest culture and mental powers may be applied to them; but their elements may be learned by young persons at school, and a foundation may be laid on which they may build the highest and most successful prosecution of the most useful of all arts.

§3. *Uses of such teaching.*

The advantages of such a course to the young mind are many and great. It leads to the consideration of all these processes by which the great Husbandman above produces out of the earth food for every living thing, as well as to those humble imitations of them by which man seeks to effect similar results on a smaller scale. In this point of view, as a means of enlarging the mind, and enabling it to reason on natural causes, the subject well deserves the study even of those who have no direct connection with practical farming. It is, in short, an important branch of learning in natural science.

Such a course will, further, enable the young farmer to read with advantage the best works on his art, and to judge for himself as to the application of their statements to any particular case. Book farming is little respected by many good farmers, and, to some extent, deservedly so. Few agricultural books, and still fewer articles in agricultural periodicals, are really reliable. They too often state facts or experiments without appreciation of the conditions on which success or failure depended. They thus give, as truths generally applicable, special facts which are of limited value, or perhaps apply to exceptional cases only. They in this way mislead the simple practical man who trusts to them. Even good agricultural works require a certain amount of knowledge in those who read them. The

plainest statements may be misapprehended by a reader not acquainted with the precise meaning of the terms in which they are expressed. The most carefully guarded explanations may be misunderstood and misapplied by similarly unlearned readers. It thus happens that for want of scientific precision in those who write or those who read, the book farmer often incurs the loss and disgrace of costly failures, which most unjustly bring scientific farming into disrepute, being caused, not by the errors of science, but simply by the want of it. The intelligent young farmer should have enough of scientific culture to enable him on the one hand to distinguish the half truths so often presented from a complete statement of the facts and principles bearing on any particular case, and on the other to appreciate and understand the best scientific works on his profession.

The knowledge even of the elements of agricultural education will also be sufficient to enable the farmer to decide as to the application of artificial manures, and to avoid the losses caused by error and fraud in the use or manufacture of such materials. It will enable him to know the composition and properties of the soils with which he has to do, and to avail himself of the services of the practical chemist in their preservation and improvement. It will teach him to appreciate the requirements of the different crops and domesticated animals, the special uses of their varieties, and the diseases to which they are liable. It will give him enlarged views on agriculture as practised in various countries and under different circumstances, as susceptible of a vast variety of methods more or less valuable, and as intimately connected with natural laws. It will thus not only add to the productive value of his labor, but will make him love his art, and realize its true position as no mere mechanical drudgery, but a scientific and even learned profession.

CHAPTER II.

HOW MAY SCIENTIFIC AGRICULTURE BE BEST TAUGHT IN THE SCHOOLS?

§1. *General views.*

That agriculture is the most important of the arts; that in this country it is the occupation of the majority of the people; that all are largely interested in its success, and that this success is connected with the diffusion of intelligence and scientific knowledge, every one will admit; but on the questions whether it can be usefully taught in our schools, and in what way, and to what extent, there may be some diversity of opinion.

It must be admitted that it is not the province of the common school teacher to give instruction in trades or professions. It is his vocation to give that elementary training which is more or less useful in all walks of life, while special professional training belongs to schools established for such purposes, or to the practical man in his field or workshop; still it is a legitimate part of the business of the teacher, to connect, as far as may be, the subjects of his instruction with the practical work of life, and especially with those portions of it which are very generally pursued. He cannot teach the practice of agriculture,—that must be done in the field,—but he can explain its theory, or, to speak more strictly, the natural laws on which its operations depend.

Much popular misconception exists as to the relation of theory to practice in the industrial arts. There is a tendency to decry theory, as if it were mere speculation, while, on the other hand, the more learned sometimes sneer at mere practical skill, as if it were wholly empirical and des-

titute of any sound reason. The truth lies between these extremes, and may be illustrated by a familiar example from another art. A practical seaman must be able to perform all the active duties required of him in the ship—to steer, to go aloft, to reef sails; and a mere landsman may be quite helpless in these matters, however much he may know as to the theory of navigation. But the ship may be well manned with able-bodied and skilful seamen, and may yet lie helpless in mid-ocean, if there is no one on board capable of working out its reckoning and determining its course; and a landsman, a boy or a woman, may be able to do this by means of the learning taught in the schools, though quite unable to perform any of the duties of the practical seaman. The ship is equally helpless without practical skill and without science. Both must be present. It is just so with farming. The farmer must know the practical operations of his art—how to plough, to harrow, to sow, to reap; but he may know and industriously practise all these, and yet may be running his farm to ruin as surely as the seaman would his ship, if he knew not his course and distance. Here science comes to the aid of the farmer. It teaches him the nature and composition of his soil; the materials of which he exhausts it in cropping; the various requirements of different cultivated plants; the nature and uses of manures; the causes of sterility and impoverishment, and the cheapest and best modes for remedying the one and avoiding the other; and the materials necessary to renovate lands that have been already exhausted.

These teachings of science are, further, not merely clever guesses and conjectures, but the results of long and patient inquiry into facts, made by the practical chemist or physiologist, who, each in his several way, is just as much a practical man as the farmer.

It is this scientific aspect of farming which can be taught in the schools. We can teach the bearing of modern scientific discoveries on the improvement of the art, and we can thereby elevate the profession itself, make it more attractive to young persons, and contribute not a

little to the industrial wealth of the country. And let it be observed, that while on the one hand agricultural education tends to the improvement of this important art, on the other it tends to the elevation of the school and the teacher, by more closely connecting education with the practical business of life, and improving and rendering more productive an art on which education mainly depends for its pecuniary support.

For such reasons as these, while in all the more enlightened countries there are special agricultural schools and colleges, and model farms, where the science of agriculture may be prosecuted in all its details, efforts are also made to introduce the elements of the subject into the Common Schools; and this more especially by directing the attention of teachers to its study in the Normal Schools, in which their professional training is received. The amount of agricultural knowledge communicated in this way is confessedly slender. Only the merest rudiments can be taught; yet the wide diffusion of even a small amount of knowledge of principles, and the thought and inquiry which this engenders, may be of incalculable value to the country. Admitting, then, that the elements of this great subject may thus be taught, our next inquiry is—How may this be best done?

§2. *Order to be pursued.*

In studying any scientific subject, more especially in its practical applications, it is necessary to follow some regular order of procedure; and there are usually different plans which may be pursued, and which may severally have their special advantages and disadvantages. It is sometimes best to begin with general principles and rules, and illustrate them by examples; sometimes best to begin with known facts, and follow these up to general principles. Further, in any complex subject it may often be difficult to explain one part of the subject without reference to others with which the learner may not be acquainted. Now, that we may ascertain the best order

for proceeding with our present subject, let us consider the things with which we have to do. The objects of agriculture are to obtain from the soil the largest possible amount of valuable food for men and animals, and, in connection with this, to preserve the soil in such a condition that it will produce other crops in future years, and to apply the food produced in the most economical and useful manner. In attaining these ends, the farmer has to do principally with cultivated plants, with soils, with manures, with domesticated animals, and with destructive vermin and diseases.

All these subjects the farmer naturally regards in the light of experience, and with reference to practical operations. What we have to do, is to bring to bear on their explanation and improvement, the facts and principles ascertained by chemistry, physiology, and natural history, and more especially by the first of these sciences. Agricultural chemistry, in short, is of more importance than agricultural physiology, botany, zoology, or geology, though all of these are useful. We shall, therefore, make this our basis, and bring in the other subjects as we proceed. Having laid for the learner a foundation of such chemical knowledge as may appear indispensable, we shall consider the Plant, the Soil, and Manures; and having discussed these, shall proceed to apply the knowledge thus acquired, to the crops cultivated by the farmer, and to other points of agricultural practice not previously noticed.

Our arrangement may thus be as follows:—

I. We shall notice the general principles of Chemistry, in so far as absolutely necessary for our purpose.

II. We shall consider the Plant, in the following aspects:—

1. The composition of its organic part, and the sources of its food.
2. Its structures and functions.
3. Its organic products.
4. Its inorganic part or ashes.

III. We shall consider the Soil in the following particulars:

1. Its origin, and the classification of soils.
2. Its composition, and deductions therefrom.
3. Its exhaustion by cropping.
4. Its improvement by tillage, draining, &c.

IV. We shall treat of Manures, as

1. Vegetable and Animal.
2. Mineral.

V. We shall consider Cultivated Crops, with their various habitudes and diseases.

VI. We shall give some practical examples of the uses of the subject.

According to this arrangement the more theoretical part of the subject will come first; but the reader interested in the practice of agriculture should bear in mind that the earlier parts, though apparently less practical, nevertheless contain the principles necessary to the understanding of the rest.

CHAPTER III.

CHEMICAL COMBINATION AND DECOMPOSITION.

Instead of explaining the general principles of chemistry in a formal manner, we shall take a familiar example and deduce certain conclusions from it. If we take 100 pounds of pure limestone, and expose it for some time to a red heat, an invisible air or gas escapes from it, and at length we have only 56 pounds of quick lime remaining. If we have collected the gas which has been given out, its weight will be found to be 44 pounds, or as much as the limestone has lost, and it will also be found to consist of a peculiar substance known to chemists as Carbonic Acid. Limestone therefore is a *compound* substance, and can be *decomposed* or separated into two other substances. But this process may be carried still farther. We can obtain from the 44 pounds of Carbonic Acid, 12 pounds of Carbon or charcoal, and 32 pounds of a gas named Oxygen, and from the 56 pounds of quick lime 16 pounds of oxygen and 40 of a metal named Calcium. Here then we have

12 Carbon	and	32 Oxygen,	forming	44 Carbonic Acid.
40 Calcium	"	16 Oxygen	"	56 Lime.

Forming, when united .... 100 Limestone or Carbonate of lime.

First, it is evident that such a union is not a mere mixture of carbon, calcium, and oxygen; it is that more intimate union termed *Combination*, and we see that *when two bodies thus combine, the result is a third substance very different from either.*

Secondly. If we take a number of specimens of *pure* limestone from all parts of the world, we shall find them all to consist of the same substances, and in the same proportion; or if we form carbonic acid or lime by causing their ingredients to unite, it will be found that weights of these corresponding to those which are found in limestone, are alone capable of combining to form these substances. These ingredients therefore, *combine in uniform and definite proportions.*

Thirdly. If we put some pounded limestone into a glass, and pour upon it a little sulphuric acid or oil of vitriol, an *effervescence* or boiling up will take place, in consequence of the carbonic acid of the limestone escaping, and after this has subsided, we shall find that the sulphuric acid has combined with the lime, forming sulphate of lime or gypsum. In this case, then, the sulphuric acid has expelled the carbonic, in order that it might itself combine with lime. *The tendencies of bodies to combine with each other, are then not equally powerful,* so that previously existing combinations may be decomposed by the addition of new substances.

Fourthly. After having decomposed limestone, and obtained carbon, calcium, and oxygen separately, we cannot decompose these three substances, or separate anything farther from them; they are therefore termed *simple* or *elementary* bodies.

Fifthly. It is found that these principles apply to nearly all the objects known to us: that these are, like limestone, compound bodies, and that they are all composed of a limited number of simple substances, or Elements, which may be arranged as follows:

5 *Gases*—Oxygen, Hydrogen, Nitrogen, Chlorine, Fluorine.

10 *Liquids or Solids at common temperatures,—non-metallic,* Sulphur, Selenium, Phosphorus, Bromine, Iodine, Carbon, Boron, Silicon, Arsenic, Tellurium.

46 or more *Metals.*—Potassium, Sodium, Magnesium, Aluminum, Calcium, Manganese, Lead, Iron, Copper, &c.

Some of these simple substances are familiarly known in an uncombined state, for example sulphur and copper; but

the greater number are found in nature only in different forms of combination.

Let us now sum up what we have learned from our piece of limestone. It has taught us that all substances may be resolved into elements which can no longer be decomposed, that these elements tend in different degrees to combine with each other; that these combinations take place in certain definite proportions; that the compounds produced differ materially in their properties from the elements of which they consist; and lastly, that these combinations may be decomposed or again broken up into their constituent elements.

We may state these truths as follows:

(1) There are about sixty different kinds of matter known to chemists, and named *simple substances* or *elements*, because none of them can be further decomposed or subdivided.

(2) These elements have a tendency to combine with each other and to form compounds; this tendency is termed the force of *chemical affinity*.

(3) When elements combine with each other they unite *in definite proportions;* and in this respect combination differs essentially from mere mixture.

(4) When elements combine, the *properties* of the resulting compounds are quite *different from those of the constituent elements.* In this also combination differs from mixture.

(5) Two or more compound substances may combine with each other, forming more complex compounds. This also takes place in definite proportions, and produces substances having properties different from those of their constituents.

(6) Compounds may be *decomposed* into their constituent elements, and these may be caused to *recombine* as before, or to *enter into new combinations.*

(7) As the affinities of substances for each other are not all equally strong, the introduction of a new substance may cause a compound to be broken up, and the new substance may take possession of one or more of the elements present and combine with them.

(8) It is the business of chemistry to *analyze* compounds, or separate their constituent elements, and ascertain the proportions and properties of these,and on the other hand by *synthesis* to form combinations from their elements. It further applies the knowledge thus obtained to the explanation of all chemical processes in the arts and in nature.

We have in these statements arrived merely at the threshold of modern chemistry; but if these few facts and principles are fixed in the mind they will enable us to proceed.

In accordance then with these preliminary statements, plants must either be simple or compound. If compound, which it can easily be shown that they are, they may consist of two or any additional number of elements, and farther, they may all consist of the same elements, or some may consist of one set of elements and others of another. Farther, if they consist of the same assemblage of elements, these may be in the same proportion or in different proportions; and lastly, they may be combined into certain compounds, which again may be united to constitute the plants. We shall in the next chapter proceed to give answers to these questions.

CHAPTER IV.

SIMPLE SUBSTANCES OF WHICH PLANTS CONSIST.

§1. *Organic and Inorganic Substances.*

All the forms of matter which we observe on the globe, may be divided into two great classes, *Organised* and *Unorganised* matter. To the latter belong all those rocks, waters, metals, and other substances, which neither are nor have been the seat of life, and which constitute the mass of our earth. To the former belong the bodies of animals and plants, and the various substances composing them, such as flesh, blood, starch, wood, &c. These compouds, being produced by organised bodies or those possessing life and organs for its maintenance, are hence properly named Organic substances.

Organic substances are all compound, and when exposed to air and moisture, they decay and gradually disappear. When burned or exposed to heat, they are decomposed, and some, such as fat, gum, and sugar, are entirely dissipated in a gaseous state, while others, as wood and lean beef, leave a small quantity of ash. This ash, as will be afterwards seen, is an essential and necessary part of vegetable structures. It consists however of substances which the plants have taken from the soil unchanged, and which are therefore inorganic. By the mere application of heat in presence of air, or by burning, we can thus separate the mass of any organized body, a plant for instance, into two groups of substances,—the *organic*, which usually constitutes the greater part of the mass, and which burns entirely away, and the *inorganic*, or earthy part, which remains as the ashes. The inorganic matter contained in the ashes of plants, though by no means of secondary importance in agriculture, may

be left for the present unnoticed, while we attend more particularly to their strictly organic part, reserving the ashes for a subsequent chapter.

§2. *Organic Part of the Plant.*

It was before stated that all the known varieties of matter consist but of 60 simple substances; but it is a still more remarkable fact, that plants of every description, with all their endless variety of appearance and properties, consist (with the exception of their inorganic matter) of but four of these elements, Carbon, Oxygen, Hydrogen, and Nitrogen. The same remarks apply, with equal truth, to animal substances. The following table shows the proportions of these elements contained in some of the most common objects of cultivation:

	Carbon.	Oxygen.	Hydrogen.	Nitrogen.	Ash.
Wheat........	455	430	57	35	23
Oats..........	507	367	64	22	40
Hay	458	387	50	15	90
Turnips........	429	422	56	17	76
Potatoes.......	441	439	58	12	50

The numbers above refer to 1000 pounds of each seed or plant, thoroughly dried.

"To the agriculturist, therefore, an acquaintance with these four constituent parts of all that lives and grows on the face of the globe, is indispensable. It is impossible for him to comprehend the laws by which the operations of nature in the vegetable kingdom are conducted, or the reason of the processes he himself adopts in order to facilitate or modify these operations, without this previous knowledge of the nature of the elements—of the raw materials as it were—out of which all the products of vegetable growth are elaborated."* First then we shall notice the properties of these four elements of organic matter, and shall then proceed to enquire whence they can be obtained by plants.

1. *Oxygen*—In its pure state, is a gaseous or aeriform substance, void of color, taste and smell. It may be dis-

* Johnston's Lectures.

tinguished from common air by two remarkable properties. If a vessel be filled with it, and a lighted taper introduced, the flame is greatly increased in size and brilliancy, and if an animal be introduced, its vital functions are stimulated and excited to such an extent that fever and death in a short time result. Oxygen is very abundant in nature, and enters into many mixtures and combinations. It constitutes 23 per cent. of the weight of the atmosphere, where its presence is necessary to the breathing of animals, and the support of combustion. It exists in still larger proportion in water, nine pounds of which contain eight of it. If iron be exposed to air and moisture, it rusts and increases in weight. This rust is a combination of iron with the oxygen of the air, or of water; and is identical with some of the ores from which iron is obtained. Many of the ores of other metals, and the majority of rocks and earths comprising the surface of our globe, are similar compounds of metals and other substances with oxygen, so that this gas, in its pure state invisible, and only a little heavier than common air, is capable, when combined with metals and other substances, of assuming the liquid and solid states, and in these forms constitutes nearly one half of the weight of the crust of our globe, and of the bodies of its animal and vegetable inhabitants. It will be seen from the table above, that it constitutes more than one-third of the weight of most vegetable substances.

2. *Carbon*—Is most familiarly known as common wood charcoal, which consists of carbon with a small mixture of potash and earthy and other matters; it also exists in large quantity in mineral coal; black-lead is almost pure carbon; and the diamond exhibits it in its purest form. The diamond differs from wood charcoal only in being more pure, and in a crystalline* state. Porous charcoal, or that of

* If we throw common salt into water, it is dissolved, that is it becomes divided into minute particles, which are diffused through the water. If a drop of this solution of salt be placed on a piece of glass, as it dries the particles of salt unite, and become *regularly arranged*, forming little transparent cubes. This is a crystallization, and it may take place either in bodies which have been dissolved in water, or which have been melted or dissipated by heat.

wood or bones, possesses the remarkable property of absorbing from the air large quantities of gases and other exhalations, hence its use in depriving putrid meat and other decaying substances of their offensive smell; it also absorbs from water any organic substances which it may contain, and even some of the inorganic saline substances. Many of these matters afford valuable nourishment to plants; and as charcoal retains them mechanically, and is always ready to give them to the roots of vegetables, it is a valuable ingredient in soils, preventing the volatile parts of manures from being dissipated in the air. If in clearing forest land, the wood or any considerable part of it, instead of being wholly consumed, were burned into charcoal, and this mixed with the soil, a permanent source of fertility would be secured. Black vegetable mould and peaty matter, which consist in great part of porous carbon, also possess this property in an eminent degree.

When charcoal is burned it combines with oxygen, forming carbonic acid gas, which disappears in the atmosphere; and when animals breathe, the oxygen of the air which enters their lungs, combines with carbon derived from the blood, and is returned to the atmosphere in this same form of carbonic acid. This gas thus exists in the air; and as it is soluble in water, it is found in rain and springs, hence it affords to plants a supply both of carbon and oxygen: and since carbon, in its pure state, is insoluble both in air and water, this source of obtaining it is of the utmost importance to vegetation, and will afterwards be particularly considered. Carbon constitutes from 40 to 50 per cent. of the weight of *dried* plants.

3. *Hydrogen*—Is, like oxygen, a colorless gas, without taste or smell; it is however 14 times lighter than air,* and will not support life or combustion, but on the other hand is itself very combustible. Combined with oxygen, it forms water; with carbon, it forms common coal gas; and with carbon it also exists as marsh gas where vegetables are decaying in swamps. It also combines with sulphur and

* For this reason Hydrogen is used for inflating balloons.

phosphorus, and in these states is often disengaged from bogs and marshes. The latter compound (Phosphuretted Hydrogen) undergoes, when exposed to the air, a spontaneous combustion, and is the cause of the well-known "Will-o'-the-wisp" or Ignis Fatuus. As hydrogen is not found in nature in the state of purity, plants must derive that which they contain from its compounds, and principally from water.

4. *Nitrogen*—sometimes also named Azote, is a gas without color, taste, or smell; it does not itself burn, neither will it support the combustion of other bodies; and animals and plants die when confined in it. It is less abundant in nature than any of the other organic elements, yet it is found in the bodies of all animals and plants, and is absolutely necessary to their growth. It forms 77 per cent. of the atmosphere, and serves to dilute the oxygen of the air, and to prevent it from acting on both living beings and dead matter, with too great violence and rapidity. Combined with a large proportion of oxygen, it forms Nitric Acid; and in combination with hydrogen, it forms Ammonia; both of which substances, as we shall hereafter see, perform important functions in reference to the growth of plants.

It thus appears that three of the four elements which constitute the solid structures of animals and plants, are, in their pure state, invisible gases, and the remaining one is identical with ordinary charcoal; yet into how great a variety of beautiful forms and valuable products are they transmuted by nature, and how interesting and instructive must be the study of the ways in which these wonderful processes are effected. This becomes still more remarkable when we add that by far the larger part of the mass of vegetables consists of substances composed of three of these elements only—Carbon, Oxygen, and Hydrogen. Of this nature are wood, starch, sugar, &c. The substances containing Nitrogen, or the nitrogenised substances, are in comparatively small quantity in plants, though of vast importance, since they are those on which the subsistence of animals chiefly depends; for while the organic part of the

plant consists chiefly of non-nitrogenised matter, that of the animal consists principally of the nitrogenised.

When we view this subject in relation to the food of plants, it is apparent that while plants may possibly obtain some supply of the organic elements in their simple state, they must take them principally from those compounds in which they exist in nature. It becomes therefore an object of importance to ascertain the properties of these combinations, the quantity and condition in which they are found, and the degree of their utility to vegetation. The substances most worthy of consideration in this point of view are, 1, Atmospheric Air; 2, Water; 3, Carbonic Acid; 4, Carburetted Hydrogen; 5, Ammonia; 6, Nitric Acid; and lastly, the vegetable and animal substances existing in the soil.

CHAPTER V.

SOURCES OF THE ORGANIC FOOD OF PLANTS.

In our last chapter, we noticed the four simple substances which constitute the organic part of plants, and concluded with naming several compounds or mixtures of these which are found in nature, and may furnish food to vegetation. These may now be considered in detail.

§1. *Air and Water.*

1. *Atmospheric Air.*—The air which we breathe, and which everywhere invests the surface of our earth, consists of an intimate mixture of two of the simple bodies before described, oxygen and nitrogen, in the proportion of 23 parts by weight of the former to 77 of the latter. From the account before given of oxygen, it is evident that its effects on the blood of animals and on decay and combustion, are too stimulating and active to permit the continuance of the present order of nature, if it alone constituted the atmosphere; while on the other hand no animal could breathe, or organic substance decay in unmixed nitrogen. Our atmosphere has therefore been wisely composed of a mixture of these two substances, in such proportion that all necessary processes, whether chemical or vital, may derive from it neither more nor less support and stimulus than they really require.

As the air consists of oxygen and nitrogen, two of the constituents of plants, and as it surrounds on every side their stems and leaves, and even penetrates deeply into the earth around their roots, we might naturally suppose that it affords part of their nourishment. Experiment, however, appears to show that plants derive neither oxygen nor

nitrogen *directly* from the air, though it certainly acts an important part in producing and carrying to them other nutritious substances. It is the vehicle in which several of the substances next to be noticed are conveyed to the leaves and roots, and its oxygen is the cause of all those processes of decay by which the food of plants is prepared in the air itself and in the soil.

2. *Water*—Is a substance indispensable to vegetation, and which ministers to it in various ways:—

1st, Water serves as food to plants. In all growing plants water is contained in an unaltered state, and its presence in this state is absolutely necessary to their growth. But water is a compound of oxygen and hydrogen, so that if vegetables are able to decompose it, they will thereby obtain two of their constituent elements. That they can do so, has been shown by cultivating plants in close vessels, with their roots immersed in water, when it has been found that the plants so treated acquired an increase of weight which could only be accounted for by supposing that they had employed part of the water in the formation of wood, and other parts of their own structures.* It is even possible that water may thus be rendered solid in the interior of plants, without any actual separation of its elements, for wood, starch, sugar and gum, substances which enter largely into the structures of plants, contain oxygen and hydrogen exactly in the proportion in which they exist in water, so that we may consider wood, starch, and sugar as consisting of water and carbon alone; a view which will cease to appear extraordinary, when we think of the great changes of appearance and properties which always accompany chemical combination. From these and other considerations, which will appear as we proceed, it seems probable that water affords to plants the greater part of the hydrogen which they possess, and probably also a portion of their oxygen.

2nd. Water acts as the vehicle by which other nutritious substances are conveyed to plants. It is well known

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* T. De Saussure.

that a vast number of substances may be dissolved in water; the water therefore which is constantly entering the roots of plants, brings with it a portion of every soluble ingredient of the soil. When exposed to the air, water absorbs from it carbonic acid, ammonia and other gases, beneficial to vegetation, hence the rains and surface waters always contain these substances, and carry them along with them when they enter into the roots. Even snow brings down from the atmosphere these nutritious substances, and from its porous character absorbs them from the air, so that the common opinion that it assists in fertilizing the land on which it falls and is melted, is not unfounded.

3rd. Certain substances, often present in soils, have strong affinities for water, or tend powerfully to unite with it. Thus, if upon quicklime a proper proportion of water be poured, the lime still remains dry, but expands and becomes warm, while, at the same time, it increases in weight to the amount of one third. The reason of this is that the water has combined with the lime, and has become solid. In like manner, common gypsum contains 20 per cent. of water in a solid state, though these substances do not, in ordinary circumstances, yield up this water for the use of plants. Common clay also holds water in its pores, and even in the driest weather, may retain enough to keep plants green and flourishing, when soils deficient in clay are completely parched.

Although water is thus essential to the growth of plants, its presence in too great quantity, is in various ways injurious to those which are usually cultivated. One of these ways is that when the soil is soaked with water, air is prevented from entering it, and we shall soon see that this is of some consequence. Another is that too much moisture imparts what is very properly named coldness to a soil. If a dish of water be exposed to the air, it gradually evaporates or dries up, and that it may thus pass into the state of invisible vapor, the water must obtain a large supply of heat, hence arises the chilling influence of wet clothes, when applied to the body. The same effect

is produced by the superfluous water of a wet soil; nearly all the heat which such a soil receives from the sun, is spent in evaporating the water, and if this be not removed by draining, or enabled to soak downward, by the addition of some less retentive substance to the soil, the crops on such a field will always be liable to be chilled and stunted in spring, to a degree which even the heat of summer may be insufficient to repair.

The evaporation of water, however, like every other natural process, is of the highest utility. To it we owe the refreshing dew and fertilizing rain, and the kind covering of snow which protects our fields from the intensity of the frosts in winter. Its relations to plants are so important and so beautifully adapted to the purposes which they serve, that no apology will be necessary for devoting a little time to their consideration.

It was before stated that heat is necessary for the evaporation of water,—and when this heat is removed from the invisible vapor thus produced, it is again reduced to the state of water. Thus, if in summer a pitcher of cold water be placed upon a table, in a short time the outside of the vessel becomes moist or covered with globules of water. This shows that the air always contains the vapour of water, and that this vapour, when it touches a cold body, is reduced to the fluid state. These simple facts will enable us to understand the general causes of *Dew* and *Rain.*

In clear weather, the earth's surface and the air in contact with it, are warmed by the rays of the sun. But every warm body has a tendency to radiate or send forth its heat, until it becomes as cold as the surrounding objects. After sunset therefore, the earth's surface rapidly cools, until, at length, it becomes so cold that the vapour of the air in contact with it, becomes condensed in the form of *dew*, or if the cold be more inténse, in that of hoar frost. But different substances, when allowed to cool, lose their heat with different degrees of rapidity; and of course, those which cool most quickly and thoroughly, must collect the greatest quantity of water from the air.

This property also forms the basis of an arrangement beneficial to vegetation; for grass and other herbage radiate their heat more rapidly than most other bodies; and hence, "in the cool of a summer's evening, the grass plat is wet when the gravel walk is dry; and the thirsty pasture and every green leaf are drinking in the descending moisture, while the naked land and the barren highway are unconscious of its fall."

When the sky is covered with clouds, these return to the ground the heat which it loses by radiation; and when the air is agitated by the wind, its vapour is usually prevented from being sufficiently cooled for condensation, hence in cloudy and windy nights, there is no dew.

The early frosts of autumn depend on causes similar to those of dew. In autumn, plants are cooled to a temperature below the freezing point, by the radiation which takes place during a clear night; in such cases, a very slight covering, even a thin cloth, may impede radiation, and save a plant; and exposure to a slight current of air, or even facing a cloudy spot of the sky, or smoke in the air, may save particular parts of a field.

Other causes may condense vapour at various heights in the air. Moist and warm air ascending from the earth's surface, and entering cooler regions, will begin to relinquish the moisture which it contains; and a cloud will be formed which may either descend in rain, or be wafted to some distant locality. The more usual explanation of the formation of clouds, is founded on the fact, that if two equal portions of air differently heated, and both containing as much vapour as they can retain, are mixed, the temperature of the mixture will be the mean of that of the two portions of air; but this intermediate temperature will not be sufficient to maintain, in the state of vapour, all the water of both portions, and consequently water must be deposited. When therefore, in our atmosphere, a current of warm air becomes intermixed with one that is colder, a quantity of fog, mist, or cloud is produced, proportioned to the excess of the watery vapour contained in both currents, above the quantity which they can retain

when mixed. Lastly, electricity, whose agency is so manifest in thunder storms, acts, in ways not yet well understood, in accumulating clouds, and precipitating their contents to the earth in the form of rain, or, more rarely, as destructive showers of hail.

§2. *Compounds of Carbon.*

3. *Carbonic Acid*—Is a compound of carbon and oxygen, in the proportion of 6 of carbon to 16 of oxygen. Carbonic acid is a gas, a little more than one-half heavier than common air; it speedily suffocates animals, when obliged to inhale it, and it extinguishes flame. Like the other substances known to Chemists as *Acids*, it reddens vegetable blue colors, has a sour taste, and is capable of combining with *earths* such as lime, and with *alkalies* such as potash and soda.

Two of the modes in which carbonic acid is produced in nature, namely, combustion and animal respiration, were mentioned under the head carbon; but it may be formed in many other ways. It exists in large quantity in limestone and other rocks, and is given out by volcanoes, and brought to the surface by springs; it is also sometimes disengaged from fissures, &c., in mines, and accumulates in deep cellars, wells, &c., forming the "choke damp" which occasionally proves fatal to persons incautiously entering such places. When wood, straw, or similar substances, are exposed to air and moisture, a kind of slow combustion, which we call decay, commences, part of their carbon and hydrogen combine with the oxygen of the air, and form carbonic acid and water, until at length nothing remains but a coaly mass capable of little further change.

In consequence of these processes, it is evident that carbonic acid must be constantly produced and added to the atmosphere; and, if this proceeded unchecked, it would at length accumulate in so great quantity, that animal life would be destroyed. But it is found that the quantity of carbonic acid in the air does not exceed the one-thousandth part of its weight, and is not increasing.

It is also known that water is capable of dissolving more than its own bulk of carbonic acid, and consequently that rain and surface water are always impregnated with it; and it is found by experiment, that plants supplied with the air and water containing this gas, apply its carbon to the formation of wood and other vegetable products. It thus appears that the carbonic acid produced by burning, breathing, decay, and other processes, and which would otherwise contaminate the atmosphere, is employed as the food of plants, and is thus, by the wise arrangement of a beneficent Providence, made a source of supplying the most valuable substances which the earth affords to man.

4. *Light Carburetted Hydrogen*,—As its name imports, is a compound of carbon and hydrogen, and is one of several compounds formed by these substances. It is a colorless gas, less than one-half as heavy as common air; it is incapable of supporting respiration or combustion, but, when flame is applied to it, burns with a yellowish light, or if mixed with air or oxygen, violently explodes. It is abundantly disengaged from beds of bituminous coal, and is the cause of the frequent destructive explosions in coal mines. It is given off from swamps and stagnant puddles, and generally from all places where vegetable matter is putrefying in fresh water. When organic matters become putrid in sea water, they decompose the sulphates of soda and magnesia (Glauber and Epsom salts), always present in such water, and *Sulphuretted Hydrogen* is produced; this gas is the cause of the offensive smell of the mud of creeks and estuaries.

Both these substances may assist in nourishing the rank vegetation of swamps, but in the small quantity in which they exist in the air, or in the soil of cultivated fields, their influence on crops can be but trifling.

§3. *Compounds of Nitrogen.*

5. *Ammonia.*—The substances which we have hitherto noticed can furnish no nitrogen to plants; this they in great part derive from the compound now to be considered. Am-

monia is a compound of nitrogen and hydrogen (NH_3). Though composed of two gases destitute of taste and smell, and itself a gaseous substance, it has a burning taste and pungent smell. Ammonia is absorbed by water to the amount of 670 times its own bulk; when thus dissolved in water it constitutes the common spirit of hartshorn, whose taste and smell are those of the ammonia which it contains. It also combines with acids, forming salts; the most common of which are, sal-ammoniac—which is a combination of ammonia with hydrochloric acid;* and smelling salts—in which it is combined with carbonic acid. The properties of ammonia which are of most consequence to vegetation are the following:

It is produced in the decay of animal and of many vegetable substances. The strong smell of stables and of urine, and other animal matters in a putrid state, is principally owing to the escape of carbonate of ammonia; hence the wastefulness of allowing rich manures to remain exposed to the air until this valuable ingredient becomes almost entirely dissipated. It has also been ascertained that in some cases where organic substances are combining with oxygen in presence of moisture, ammonia is produced from the nitrogen of the air and the hydrogen of the water. These facts, with the gaseous nature of ammonia, show that it must always be present in the air, as, indeed, experiment actually proves.

It is very soluble in water. The ammonia which the careless farmer allows to escape from his stable and dung heap is not lost, but only added to the general stock of nutriment for vegetation. Every shower washes from the air a quantity of ammonia; and to this the rain water owes both its softness and its superior power of nourishing plants, compared with pure water. It has been proved by experiment that the average quantity of ammonia deposited by the rain on an acre of ground in one year amounts to about 23½ lbs. The moisture of the soil also

* A compound of Hydrogen with the element Chlorine, to be noticed farther on.

serves to retain, and convey to the roots of plants, the ammonia produced by the decay of manures which may be buried in it.

It can easily be decomposed, and also separated from other substances, when combined with them. From the first property it cannot be doubted that it may, if necessary, when introduced into the cells of plants, be divided into its constituent elements, and those applied to purposes of nourishment. And of the latter, the readiness with which its compounds undergo changes when exposed to the action of other bodies, furnishes conclusive evidence. When, for instance, lime is added to animal manures, a strong smell of ammonia is instantly exhaled, and hence the injurious effect of lime when applied to such substances. When lime is buried in the soil, however, this decomposing power may serve to set free ammonia, in circumstances favorable to its being absorbed by plants.

When common gypsum (sulphate of lime) comes into contact with carbonate of ammonia, a *double* decomposition takes place; or the carbonic acid and sulphuric acid change places, and sulphate of ammonia and carbonate of lime are produced, so that

$$\left.\begin{array}{c}\text{Carbonate of Ammonia}\\ \text{and}\\ \text{Sulphate of Lime.}\end{array}\right\}\text{ are changed into }\left\{\begin{array}{c}\text{Sulphate of Ammonia}\\ \text{and}\\ \text{Carbonate of Lime.}\end{array}\right.$$

Now carbonate of ammonia, as before stated, evaporates rapidly when exposed to the air; whereas the sulphate of ammonia is not thus volatile; and the circumstance of a volatile salt of ammonia being thus changed by the agency of gypsum into one that is fixed, is of great assistance to the farmer. Thus when gypsum is strewed on the floor of a stable, the carbonate of ammonia—which is formed in such places—instead of being permitted to escape into the air, becomes converted into the sulphate, and remains united with the gypsum; every pound of gypsum thus saturated with ammonia is able to supply all the nitrogen required by twelve pounds of wheat. Of all the manures produced on a farm, urine is undoubtedly the most valuable; but a great part of its utility depends upon the quantity of nitrogen which it contains; and if it be allowed

to dry up alone, much of this escapes as carbonate of ammonia: this loss also may be prevented by gypsum. A part of the influence of gypsum, when strewed upon fields, may also be explained by this property; for the gypsum lying on the soil, not only fixes and prevents from escaping the ammonia which may rise from the ground, but attracts it from the air; and thus, from the very winds that blow over the soil, it gathers valuable nourishment for the growing crops.

Ammonia is largely absorbed by various substances. Powdered charcoal absorbs ninety times its bulk of ammonia, and decayed wood seventy-two times its bulk; hence these substances, when plentifully contained in a soil, are capable of collecting and retaining, for the use of plants, an abundant store of nitrogen. In a manner somewhat similar, burned clay, coal ashes, and the red oxide of iron (red ochre) absorb ammonia from the air. The effects of burned clay as a manure, and the fertility of those bright red soils which are colored by oxide of iron, are partly to be ascribed to this cause.

By referring to the little table of the composition of wheat, oats, &c., formerly given, it will be seen that nitrogen constitutes but a small portion of these and other vegetable substances. From this, however, we must not conclude that nitrogen is of little importance. All those parts of plants which afford the most valuable articles of food to animals contain nitrogen; and the production of such nutritious substances is the principal object of agriculture. Wheat contains more nitrogen than oats, and these more than potatoes; and the nutritive powers of these three crops are nearly in proportion to the quantity of nitrogen which they contain; so also, in some degree, are their values in the market. It must always be an object with the farmer to produce the most nutritive and valuable crops; and since these are the crops which contain the most nitrogen, it must be of importance that he should supply as much as possible of this element to his fields. Hence one part at least of the great value which experience attaches to guano and the richer animal manures, which

either contain ammonia, or are capable of yielding it in the soil.

6. *Nitric Acid*—Is a compound of nitrogen and oxygen (NO^5), and, when dissolved in water, is the substance commonly known as aquafortis. It combines with a great number of substances, and it is in these states of combination that it is usually found in nature. Common saltpetre is composed of nitric acid and potash. When applied to plants, nitric acid and its compounds act by supplying nitrogen, and perhaps also oxygen. In some plants, such as tobacco and the beet, which contain much nitrate of potash, it remains in an unaltered form.

In warm climates, decaying animal matters often produce nitric acid instead of ammonia: this, however, does not so often occur in temperate regions. If heaps of earth, mixed with decaying matters, be left for some time exposed to the air, and if the earth be afterwards washed with water, a quantity of nitrates of lime, potash, &c., will be obtained from it. In France and Sweden, saltpetre for the manufacture of gunpowder is obtained in this way. The sides of limestone caverns, the mortar of cellar walls, the earth of mud dykes, and compost heaps, become impregnated with nitrates in a similar manner. In the district of Arica in Peru, deposits of nitrate of soda are found beneath the soil, and the mineral dug thence is exported to Britain, where it is advantageously employed as a manure. In France it has been found that the rain annually deposits about thirty pounds of nitric acid on each acre.

In this climate nitric acid and its compounds cannot be so abundantly obtained as ammonia, and are not so much under the control of the husbandman: but whenever they can be procured, in any of the ways noticed above, they will be found very beneficial.

§4. *Organic Compounds.*

7. *The Organic Matters contained in the Soil.*—Every fertile soil contains a portion of vegetable or animal matter produced from plants which have grown upon it, or arti-

ficially added in the form of manure. Such matters have always been considered very efficacious in increasing the productiveness of a soil; we must therefore now enquire how, and to what extent, they can afford nourishment to crops. This enquiry becomes more important, when we consider that all the substances hitherto noticed are furnished to vegetation by the atmosphere, and consequently, that if plants really derive any organic matter from the ground on which they grow, it must be furnished by the substances now to be considered.

In the very outset of this investigation, we find some facts which limit the amount of influence attributable to organic manures.

1. Their very nature shows that they themselves are products of vegetation, so that a time must have been when there was no vegetable mould. The first plants that grew in any place must have been nourished solely by dead inorganic matter.

2. In accordance with this, it is found that plants supplied with air, water, carbonic acid, and ammonia, (or watered with rain water, which contains the other substances), will grow in sand or clay altogether destitute of animal or vegetable manure.

3. Plants growing in a wild state add to, rather than diminish, the quantity of vegetable soil. Land left long in grass, or covered with forest trees, becomes richer in vegetable mould; green crops, such as clover, when ploughed in, act as manure to soil, which would be impossible if their own substance had been derived from it; and in moist places, vegetables often add to the soil so much organic matter that thick beds of peat become accumulated.

It is evident, therefore, that plants can obtain from the air and water substances such as the first six compounds which have been described, can convert them into vegetable matter, and when they die, leave this to form vegetable mould. But it is equally evident, from the experience of all farmers, that organic manures greatly increase the luxuriance of crops. This may be accounted for in the following ways:

1. Some organic substances, such as gum and sugar, are soluble in water, and when plants are watered with solutions such as these, their vigour is increased. It is, however, plain, that no manure applied by the farmer can contain much matter of this kind, and very little of it can be left in the soil by plants which decay where they grew.

2. Vegetable matters placed in the soil soon begin to decay or ferment; and in the earlier stages of these processes several substances are produced different from any which existed in the living plant, but perhaps capable of being taken into the sap of other vegetables, and aiding their growth. Most of these substances produced in decay are, like woody fibre,* compounds of oxygen, hydrogen, and carbon, but in different proportion; and many of them are acids, so that they are capable of combining with lime, potash, and similar substances, and of carrying them with them into the roots of plants. Two of the best known of this class of substances have received the names of *humus* and *humic acid.* The former is merely woody fibre in a particular stage of decay, and the latter is produced from humus, when potash or other alkalies are brought into contact with it.

3. The final result of the decay of animal and vegetable matters in the soil is, that they become resolved into ammonia, carbonic acid, and the other substances which we have already considered; and their slowly producing these around the roots of plants, probably explains a large portion of their efficacy as manures. It also partially explains the utility of loosening and pulverizing the soil; for decay being a slow process of combustion, air is necessary in order that the manures may be rendered available, and this is more readily admitted into the loosened soil.

4. We must not forget that all vegetables yield a quantity of ashes, or inorganic matter, and this also is set free when they decay in the soil. Their effects in this

* Woody fibre is best known in the form of wood of trees but the stems, roots, and leaves of nearly all plants, in great part consist of it.

way cannot at present be considered, but we shall hereafter see that they form a most important part of the action of organic manures.

5. Organic substances improve the color of the soil, darkening it to such a degree that it becomes more absorbent of solar heat. They also improve its mechanical texture, and render it more absorbent and retentive of soluble and volatile manures.

While, therefore, plants can obtain the greater part of their organic constituents from the winds and rains of heaven, they are also greatly assisted by the presence, near their roots, of matters which have already formed part of organised structures. These are particularly important in the earlier stages of growth, as a plant which is enabled by their means to attain a state of vigorous health, will possess a greater power of attracting and assimilating substances not yet organized, than its more weakly neighbors, which have been forced from their very infancy to depend upon the kindness of nature for a subsistence; hence the improvement which careful cultivation can effect in vegetables of every kind; and hence the luxuriant herbage which springs from the well-manured fields of the careful and industrious farmer, is able, by means of its well-developed roots and abundant foliage, to use, in its own increase, all the matter brought by air or water within its reach, while these bounties of Providence are in a great measure lost to the starveling crops of an impoverished farm.

§5. *Recapitulation.*

Before leaving this part of the subject, it will be useful to repeat the most important of the conclusions deducible from what has been already stated.

We have seen that plants consist of *organic* substances, differing from any forms of dead matter, and of *inorganic* matters derived from the mineral matter of the soil.

The organic part of plants we have found to consist of three gases, oxygen, hydrogen, and nitrogen, and one solid

substance, carbon; and these are obtained in the following ways:—1st, The *Oxygen* of plants is obtained principally from water and carbonic acid. 2ndly, Their *Carbon* is nearly all derived from carbonic acid. 3rdly, Their *Hydrogen* is obtained principally from water, but probably in part from ammonia. 4thly, Their *Nitrogen* is principally derived from ammonia, and partly from nitric acid. 5thly, A portion of all these substances is obtained by plants from the remains of other vegetables which have existed before them. In general, plants derive the materials of their organic part from water, carbonic acid, and ammonia or nitric acid, floating in the atmosphere, or brought down in rain and dew, or disengaged in the soil; and in so far as this part of the food of plants is concerned, it chiefly belongs to the farmer to supply to the soil substances capable of affording ammonia, or nitric acid, and carbonic acid. Some of the reasons why these views of the supply of food to vegetation should be adopted, as well as some of their practical applications, have already been mentioned. They will, however, more fully appear, after we have examined the *structure of plants*, and the means by which they convert their food into the various substances for which they are cultivated.

CHAPTER VI.

THE STRUCTURE OF PLANTS.

§1. *General Structure.*

The substances which we have viewed as constituting the food of plants, when taken into the system of a vegetable, have entered into a chemical and vital laboratory, where they are destined to undergo a series of changes, ending in their assuming forms and properties very different from those which originally belonged to them. It is therefore necessary that we should consider the *organs* of plants; the vessels or utensils as it were, which nature employs in converting the unorganized matter of the soil and air into food for men and animals.

The *general structure* of all plants is nearly the same. The wood of the hardest tree, as well as the stem of the most delicate herb, is composed of an immense number of very small tubes and cells, whose sides consist of woody matter, enclosing cavities suited for containing or transmitting sap or other fluids. These cells and tubes assume many different forms, varying from those of nearly round bags or bladders, to those of long pipes, sometimes extending through the whole length of a plant. They also differ very much in dimensions, direction, and mode of arrangement; and it is to these differences that we must ascribe the various degrees of coarseness and fineness, toughness and brittleness, hardness and softness, which we observe in the wood of different trees, as well as the various kinds of texture which appear in the organs of every individual plant. To examine these varieties of structure, and the purposes which they serve, is a pursuit full of interest and

instruction; for the present, however, we must content ourselves with a very general outline of the subject, taking for our example the structure of trees, which are the largest and most perfect specimens of vegetation.

The trunk and branches of a tree may be viewed as consisting of three parts—Bark, Wood, and Pith. The true *Bark* consists of a tissue of cells, closely embracing the tree, of a white or brownish color on the older parts of the trunk, and green on the young extremities of the twigs. This inner or true bark is covered and protected from the air by an outer skin or covering, which in some trees, as the white birch, consists of numerous thin and tough layers. In some plants, as the grasses, this outer bark is the only external covering which appears, and in these plants it often consists in part of dense inorganic matter, constituting the strongest part of the stem. The *Wood* is principally composed of cells and vessels of various forms and sizes, arranged lengthwise in the stem, and crossed by bundles of cells placed horizontally, and extending from the centre of the wood to the bark, so as to form thin plates stretching across the wood, and called the *silver grain*, or *medullary rays*. The office of these is supposed to be that of conveying fluids from the bark to the heart of the tree. The *Pith*, which is present only in young branches and small stems, consists of large cells placed horizontally, and it probably serves to store up superabundant sap till it is required by the plant. These structures, though most obvious in the trunk, are continued into the branches, and, in some degree, into the leaves. Though the structure which we have noticed prevails in trees, and in a great number of herbaceous plants, there is a large proportion of the vegetable kingdom which shows no regular arrangement of bark, wood and pith; and the whole of the grains and grasses are of this last kind. In these plants, however, the parts discharging the different functions of wood and bark are not wanting, but rather intimately united instead of being separated into different portions. We may now consider the functions of those organs which belong to nearly all plants.

§2. *The Root.*

The larger branches of the root, like those of the trunk, consist of bark and wood; but in their smaller ramifications both bark and wood become soft, porous, and easily penetrated by water; and these minute and greatly divided extremities of the roots, penetrating to every part of the soil around a plant, are its true mouths or feeders.* The spongy rootlets are capable of taking only fluid food; no particle of clay or other undissolved matter can enter them; they absorb water, and this in so large a quantity that a sunflower three feet high has been stated to draw from the soil thirty ounces of water in twelve hours of a sunny day. But the water of the soil is not pure; it contains a great variety of mineral and other substances in solution, and these it must carry to the roots of every plant which grows upon it. Do all plants then, which can grow on the same soil, require from it the same kinds of food? Experiment shows that this cannot be the case. If a pea and a plant of wheat grow side by side, and if both be gathered and burned, the ashes of the wheat will be found to contain a large proportion of silica or flint, which served to strengthen its straw, while those of the pea will be found to afford scarcely any of this earth. The water of the soil must have brought a certain quantity of silica to the roots of the pea as well as to those of the wheat, but by the former plant it was rejected as useless, while to the latter it was absolutely necessary. It becomes therefore an interesting question whether the roots themselves have the power of selecting from the soil what is required by the plant, or whether they absorb all matters indifferently, and leave to the other parts of the plant the office of selecting the most proper kinds of food.

This point has been much disputed, it may however be

* Hence, in transplanting, great care should be taken to preserve uninjured the small fibres of the roots. Plants should not be carelessly "torn out of one place and thrust into another."

rendered more simple by a reference to animals. Of these we know that every species is endowed with the skill necessary for choosing the most suitable nourishment, and yet that the ordinary food of each includes much that must be afterwards rejected; while all are liable occasionally to mistake what is poisonous for what is nutritive. In the same manner it can be shown that plants altogether refuse to receive some substances even when placed in contact with their roots in a soluble state; and yet that they do absorb much which they afterwards reject, and in some instances that they admit matter which proves highly injurious or poisonous to them. In plants also, as in animals, there are always matters of various kinds, which have served some purpose in their economy, but have finally become useless; and the roots of plants are the organs by which the excretion of these matters is effected.

The substances thus excreted by plants, are either organic or inorganic. With respect to the former, Macaire found that vegetables carefully taken from the ground, and placed in water, gave forth from their roots substances having the properties of gum, extractive matter, opium, and other organic compounds; more recent observations, however, have shown that at least a part of these effects is due to the escape of the juices from wounded parts of the roots. A better instance of the excretion of organic matter is furnished by the fact, that when grain is made to sprout in powdered chalk, after germination has taken place, a part of the chalk (carbonate of lime) is found to be converted into acetate of lime; acetic acid (vinegar) having been produced in the young plants and given out by their roots to combine with the lime.

The quantity of *inorganic* matter voided by plants is well shown by some experiments of De Saussure. First: he found that after vegetables have attained nearly to their full growth, they yield much more ashes, in proportion to their own weight, than afterwards, when the seed is ripened; thus a plant of wheat, when ripe, contained less than one half the proportionate quantity of ashes contained in a plant before flowering. Secondly: that this was

caused by an actual return of inorganic matter to the soil, and not by an excess in the growth of the organic parts, was shown by the circumstance, that while the whole quantity of ash diminished, some of its ingredients greatly increased in quantity. Thus wheat contains a large proportion of silica, and it was found that the quantity of this earth in the ripe plant was to that in the green in the proportion of four to one, so that the other ingredients must have been lost to a much greater extent than the proportion before stated. Thirdly: the quantity of silica contained in the ashes of wheat affords in another way a proof of the excretion of inorganic matters. Silica alone cannot be dissolved in water, but when it combines with potash, soda, or other alkaline substances, in certain proportions, it becomes soluble, and in this state it enters into the vessels of plants. Silica however requires nearly half its weight of potash or soda to render it soluble, and on examining the ashes of ripe wheat, it was found that the quantity of silica which they contain is four times that of their alkaline matter; or that there is present in the ripe plant only half the quantity of alkali required for the solution of the silica which it contains. It is evident therefore that a portion of potash or soda has been separated from the silica with which it was combined, and has been expelled, and perhaps this process may take place repeatedly, so that a small quantity of alkali may be the means of introducing much silica into the straw of wheat. Plants have therefore the power of sending back to the soil useless or injurious substances, whether obtained unaltered from the ground or formed in their own system; and it is even possible that some of the matters thus ejected may, as in the case of the alkali just noticed, combine with substances in the soil, and thus become fitted to be again absorbed with beneficial results.

The well known benefits of a rotation of crops have been attempted to be explained by supposing that the excrements disengaged from the roots of a plant, must be hurtful to others of the same kind if planted in the same soil, while on the other hand they might be nutritive to plants

of other kinds. Thus if the roots of a pea be placed in water, they communicate to it in time a brown color, in consequence of gummy secretions being thrown off from the plant; and if, after the water has thus been filled with excrements, another plant of the same kind be placed in it, it will not flourish; but if, instead of a second pea, we place in it a plant of wheat, this will grow luxuriantly and take from the water a part of the matter previously deposited in it. In the same manner, the soil in which any species of vegetable has long been cultivated may become surcharged with its excrements, and the substitution of some other crop, which can free the soil from these, may be rendered necessary. It is evident that the *inorganic* matters rejected by plants cannot have much influence in this way, since these previously existed in the soil; and we shall afterwards see that the quantity of these mineral matters *taken from the ground* and not returned to it, is one very powerful cause of the rapid deterioration of plants when long cultivated on the same soil. The *organic* excretions derived from that food which is obtained from the elements afforded by air and water, are alone capable of rendering the soil poisonous to the plants from which they proceeded. We must not, however, forget that these secretions may, like other organic matter, be decomposed; so that, after a sufficient interval, their injurious effect must entirely cease; hence it is found that fallowing, which gives time for the excrements in the soil to decompose, may on this account be substituted for a rotation of crops.

The latest experiments and observations on this subject seem to show that the organic excretions of plants have practically little effect on their culture, and that the extent to which they remove mineral matter from the soil is really the principal cause which renders the soil unsuitable to them. This we must consider under another division of our subject.

§3. *The Ascending Sap.—The Stem.*

The water absorbed by the roots is carried upward into the stem, becoming, in its progress, more or less mixed

with the fluids existing in the plant. In consequence of this intermixture, and probably also of changes effected by the agency of the cells and vessels through which it passes, the sap of trees, even in the lower part of the trunk, differs much from the water which the roots are sucking from the soil. Thus in spring, the sap of the maple is rich in sugar, a substance which it could evidently not obtain from the water in the ground. The presence of this sugar is due to several causes—1st, the water and carbonic acid drawn up from the soil contain the elements of sugar, and may possibly be converted into it by the action of the wood, or of the young buds; to what extent such transformations can be effected by the wood, is not however very certain. 2nd, many trees store up in autumn a quantity of starch, and possibly other substances, in the cells of their stems and roots; and that the starch thus prepared may be rendered useful in advancing the growth of the young leaves, the first process necessary is its conversion into sugar, a change as will afterwards be seen, very easily effected. 3rd, in spring, before the leaves are developed, growth is going on very slowly, and the sap not being used in the formation of wood and leaves, is allowed to accumulate in the wood, and when the tree is stimulated by the light and heat of the sun, may be obtained by tapping it. But as soon as the leaves are formed, the sap is rapidly withdrawn to furnish materials for their growth, and for the formation of wood; and for this reason it cannot then be obtained in the same quantity or of the same quality as in early spring.

§4. *The Leaves.*

A leaf, as it appears to the unaided eye, consists of a framework of tough fibres, proceeding from its stalk, and branching over it in every direction; on these are stretched two skins or membranes forming its upper and under sides, and the space between these is filled with soft and pulpy matter. When examined with the microscope, other structures appear. The surfaces of the leaf, especially the lower one, are found to be perforated with numerous minute

openings, communicating with small cavities in its interior; the green matter is found to consist of cells filled with a soft green substance; and the fibres are found to be formed of vessels similar to those of the wood. Into the leaves thus constructed, the sap is conveyed from the stem by means of the stalk and fibres; from these it passes into the cells of the green matter, where it is exposed to the action of the external air, and of the light and heat passing through the outer membranes. Under the influence of these powerful causes of chemical change, the leaf becomes the seat of important processes.

1. A large portion of the water of the sap escapes from the leaves by evaporation and perspiration. Water contained in a vessel in which the roots of a growing plant are placed, is gradually drawn up and given out by the leaves, until at length, if not renewed, it becomes altogether exhausted; and then the plant droops and withers, because the leaves are rapidly exhaling its fluids, while the roots are receiving no new supplies. This emission of water proceeds with the greatest rapidity when the plant is exposed to the direct rays of the sun, and in darkness it becomes very slow or ceases altogether. Thus the sunflower, which, in a sunny day, can give off 30 ounces of water, emits only 3 in a dry night, and none in a dewy one. In consequence of this rapid escape of water, the substances which it held in solution are left in a more concentrated state, and ready to be deposited wherever they are required. The large quantity of water which thus passes through their system, also enables plants to obtain from the soil abundance of many substances which are contained in it in very small quantity, or are with difficulty soluble in water.

The powers of the leaves, with reference to water, are not limited to exhalation; they also in some cases can absorb it from the atmosphere, or from the rain and dew which falls upon them. It is thus that drooping plants may be revived by watering their leaves, and thus that the air plants of China and Buenos Ayres flourish when suspended from the walls and balconies of houses, without any connection with the ground.

2. The leaves absorb and decompose carbonic acid, a gaseous substance, which, as before stated, exists in small quantity in the atmosphere, and is the principal source of the carbon in plants. If a vegetable be confined in a glass vessel containing air, with the usual proportion of carbonic acid, or having a little more artificially added, and then placed in the sun, after some time it will be found that a part of the carbonic acid has disappeared, and that a quantity of oxygen corresponding to that which it contained, occupies its place. This change is effected by the leaves, which therefore have the power of absorbing carbonic acid and retaining the carbon, at the same time expelling its oxygen.

But while this process proceeds with rapidity in sunshine, it goes on much more slowly in the shade, and in darkness gives place to one of a contrary nature. The leaves, which by day receive and decompose carbonic acid, by night emit carbonic acid and absorb oxygen. In plants growing in ordinary circumstances, the former process is carried on to a much greater extent than the latter, which appears in some respects to serve for resting and renewing the exhausted powers of the leaves.

The decomposition of carbonic acid by the leaves of plants, is most important to their growth, because upon the carbon thus fixed in their structures, their strength and solidity in a great measure depend; and as this decomposition can only proceed in the presence of air and light, plants cultivated where these are deficient, become blanched, slender, and watery. For the same reason, potatoes and other vegetables, cultivated for the starch and similar substances contained in their roots, are unable to obtain the necessary quantity of carbon, and in consequence produce a crop of inferior quality, when cultivated in the shade, or too thickly crowded. It is thus also that where plants can obtain light only in one direction, they grow toward it; for the side next the light being able to fix more carbon, becomes firm and woody, while the other, being soft, extends more rapidly, and hence the stem bends toward the light. From the same cause the wood of trees which have grown

in open ground, is more hard and durable than that of those which have lived in thick forests.

3. The leaves absorb and emit other gaseous bodies beside carbonic acid. Experiment shows that the leaves cannot absorb nitrogen directly from the air, but that they readily absorb the ammonia and nitric acid floating in it, and, by decomposing these obtain the nitrogen required by the sap. The various odours and perfumes exhaled by many leaves and flowers are all volatile matters, formed in their cells and vessels, and which would probably be injurious if retained.

In the leaves then, the sap loses much of its water, receives an additional quantity of carbon, and is subject to other changes afterwards to be considered; thus altered it passes into the vessels of the bark.

§5. *The Bark.*

The principal office of the inner bark is to apply to the formation of new tissues the substances contained in the thickened sap which it receives from the leaves. For this purpose this fluid is carried downward, adding new matter to the outer surface of the wood, and the inner surface of the bark, and penetrating by the medullary rays to nourish the interior of the tree. In this manner it returns to the roots, by whose extremities its waste and useless portions are probably returned to the soil; and the remainder, becoming mixed with the ascending sap, is again carried upward to the leaves. In some plants, such as the grasses, which have no true bark, the descending sap probably passes through a particular set of vessels, which are mingled among those which carry the ascending sap.

From the very short and general view which we have taken of the nutrition of vegetables, it appears that their food is obtained from the water contained in the soil, and by the leaves from the atmospheric air; that the substances obtained from both these sources are united in the leaves; and that they there undergo changes fitting them for being converted into the various matters which are found in the roots, stems, and fruits of plants. The nature of these changes, and of the substances which result from them, are next to be considered.

CHAPTER VII.

ORGANIC COMPOUNDS PRODUCED BY PLANTS.

§1. *General Statements.*

We have seen that carbonic acid, water, ammonia, and other substances which form the food of plants, are taken into their cells and vessels, and constitute the raw material which affords the carbon, oxygen, hydrogen, and nitrogen required for the formation of their tissues and products. Nothing in nature is more wonderful than the processes of organic chemistry, by which the plant succeeds in forming out of so few elements all that almost endless variety of woods, resins, oils, gums, acids, sugars, and other matters which are contained in plants, and which can, for the most part, be prepared in no other way than by the agency of vegetable life.

It is to the presence of different compounds of these descriptions that vegetables owe the diversity of tastes, odours, colors, and of nutritious, poisonous, or medicinal properties, which we find in different plants, and in different parts of the same plant; a diversity so great that we can scarcely help considering every vegetable to be endowed with the power of arranging in ways peculiar to itself, the simple substances contained in its food.

To examine in detail all this vast variety of vegetable products, and endeavour to discover the causes of their production, would form an interesting study; but it would lead us far from the applications of chemistry to common agriculture, and would involve us in some of the most difficult questions in the science; questions many of which are yet unanswered, or but very imperfectly understood. There are however, some of these substances so generally

diffused among plants, or so valuable to man, that they must receive our attention, if we would wish to know of what the produce of our fields consists, how it is prepared, or how it can be best obtained. We may for our present purpose divide these substances into two groups, the Non-nitrogenised and the Nitrogenised.

§2. *Neutral Non-nitrogenised Substances.*

The greater part of the substance of vegetables consists of compounds destitute of nitrogen, containing therefore only three of the four organic elements. Of these substances we may notice:

1. *Cellulose or Woody fibre*, so named because wood is almost wholly composed of it. It is present in the stems, roots, and leaves of nearly all plants, forming the sides of their cells and vessels; and hemp, flax, and cotton consist of cellulose nearly in a state of purity. When the wood of different trees is analyzed, it is found to vary somewhat in its composition, probably because the cells and vessels of wood become incrusted or partially filled with another matter named Lignin, which cannot be separated from the true woody fibre. It is perhaps for the same reason that the composition of cotton, pith, and the cellular matter of soft vegetables, is found to differ from that of the wood of trees. This difference appears in the following table:

	Oak Wood.	Cellular matter.
Carbon	50.00	44.80
Hydrogen	6.20	6.20
Oxygen	43.80	49.00
	100	100

The most remarkable fact shown by these analyses is, that the quantity of oxygen is nearly 8 times that of the hydrogen; or, in other words, that these two elements are in the *proportions required to form water;* so that woody and cellular matter may be viewed as composed of char-

coal and water; though it is evident that the water or its elements, which thus compose more than half the weight of wood, must be in a very different state from that in which this fluid is usually found.

According to the rule of definite proportions formerly stated, considering the *equivalent* of carbon to be 6, that of oxygen 8, and that of hydrogen 1, and dividing the quantities given above by these numbers, we find the shorter and more accurate expression for the composition of the cellulose or cellular matter to be: *

$$C^{12}\,H^{10}\,O^{10}$$

2. *Starch.*—This substance is, like wood, contained in nearly all plants, but in a different form and for different uses. While wood is the material of the cells and vessels, starch is at particular seasons stored up as a reserved stock of food, to be employed when other supplies fail, or when a growth more luxuriant than ordinary is required. Many plants whose stems die in autumn, form large roots or underground stems, containing matter fitted to send forth and nourish vigorous shoots in spring, and this matter very frequently consists in great part of starch. The tubers of the potato, for instance, are constructed of cells, each of which contains several little grains of starch, destined, if not used as food by animals, to be drawn off by the vessels of the sprouting "eyes" in spring. Grains of all kinds, and many other seeds, contain large quantities of starch, destined to furnish the first food to the seedling plant. Thus wheat contains from 39 to 77 per cent. of starch; barley 67 to 70; oats, 70 to 80; rice 84 to 85. Starch therefore forms a large part of bread, and most other kinds of vegetable food; in using which we are applying to the promotion of our growth what plants have prepared for theirs.

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* In any chemical text-book the learner will find the table of *chemical equivalents* or combining values of substances, according to which these formulas are framed.

Starch when pure is colorless and tasteless; it is not dissolved by cold water, but in boiling water it is readily soluble. It consists of carbon 44, hydrogen 6.2, oxygen 49.8, in 100 parts, so that its composition is the same with that given for cellular matter, and may, like it, be represented by $C^{12}\ H^{10}\ O^{10}$.

3. *Gum.*—Of this substance cherry gum and gum Arabic are good examples. It is found in the state of mucilage in the sap of all plants, and in nearly all those roots and seeds used for human food. Gum dissolves in water, forming mucilaginous solutions; that obtained from different plants differs in solubility, some varieties being soluble only in hot water, others in cold, and others forming a kind of jelly. The composition of gum is the same with that of starch, $C^{12}\ H^{10}\ O^{10}$.

4. *Sugar.*—The most familiar example of this substance is common cane sugar, which is found abundantly in the sugar cane, maple, Indian corn, beet, and various other plants. The composition of cane sugar differs little from that of starch and gum. It is $C^{12}\ H^{11}\ O^{11}$.

In a number of plants, varieties of sugar are found, differing somewhat in chemical constitution from that of the cane. The most important of these is *grape sugar*, which contains more of the elements of water than any of the substances before noticed, its composition being $C^{12}\ H^{12}\ O^{12}$. This sugar is less soluble in water and less sweet than the common variety. It is found in honey, in germinating seeds, in fermented liquors, in the grape, gooseberry, apple, plum, and most other fruits. It is therefore especially the sugar of fruits and growing seeds, as cane sugar is especially that of the general sap.

Before proceeding farther, we may pause for a little to consider some of the *mutual relations* of the four substances which have just been described. They are produced by vegetables in greater abundance than any other substances, and are concerned in most of the changes which take place by the agency of vegetation. That they may be more readily obtained by all plants, they are composed of carbon, oxygen, and hydrogen alone, so that

whenever carbonic acid and water are present, the materials for their formation can be obtained; and these, as we have already seen, may be found in every place where vegetation can subsist.

While they all consist of the same elements, they contain them in the same or nearly the same proportions. In this respect we may indeed regard them as only one substance, capable of assuming several different forms; in its soluble states of gum and sugar circulating in the sap, and supplying nourishment to every organ, and in its more insoluble forms stored up as starch for future nourishment, or fashioned into tough woody walls of cells and vessels.

That these substances, thus nearly related, may be changed from one form to another, that sugar may be converted into wood or starch, and gum into sugar, and *vice versa*, we have abundant proof in many common processes. If barley be moistened and thrown into a heap, as in the process of malting, as soon as it has sprouted we find a great part of its starch converted into sugar; the sugar of the beet or of maple sap, when these plants begin to grow in spring, soon disappears and becomes converted into woody stems and leaves; and when a potato is planted and begins to grow, its starch furnishes the material for its stems and foliage, after having first been taken up in the sap in the form of gum and sugar.

Such changes as these may be produced by art, and by examining how this is done, we may be better able to understand how they occur in the living plant. They may be effected,

1. *By heat.*—If sawdust be carefully washed, then dried in an oven till it becomes crisp, and afterwards ground, the wooden flour thus produced, if boiled in water, forms a jelly like that from starch, and when fermented and baked, gives a light and not unpalatable bread. By merely applying heat and moisture, we can thus convert woody fibre into starch. Again, starch, when exposed to a heat below 300°F. becomes yellow or brown, and in this state is soluble in cold water, and in other respects has the properties of gum. Starch changed in this way is called

British gum, and forms a good substitute for gum Arabic. Lastly, in the manufacture of British gum, a portion of the starch is sometimes changed into sugar. Heat, therefore alone is capable of transforming starch into gum, and gum into sugar.

2. *By Acids and Alkalies.*—If to a quantity of fine sawdust or linen rags, we add more than its weight of sulphuric acid, and rub the mixture in a mortar, the wood or linen will be converted into jelly and then into gum. If to the gum thus produced we add more sulphuric acid, and a quantity of water, and allow it to stand for some time, the gum will be found changed into grape sugar. Any of the varieties of wood, starch, or gum, may thus be converted into sugar; and in France potato starch thus transformed is employed to some extent in the manufacture of brandy and fermented liquors. 100 lbs of starch mixed with 600 of water, and 10 of sulphuric acid, by boiling for seven or eight hours, produce about 112 lbs. of grape sugar.*

Cane sugar may also by the action of acids be readily changed into *grape* sugar; and it is for this reason that fruits preserved in sugar often become candied. The vegetable acids of the fruit convert the cane sugar into grape sugar, and the latter, being less soluble, crystallizes in little lumps.

Alkaline substances are also capable of effecting some of these transformations. If sawdust be boiled in a strong solution of pure potash, a portion of the woody fibre will assume the properties of starch.

Since we can so easily, by artificial means, produce these transformations, it cannot be doubted that they can be still more readily effected within living plants. Human art can, however, imitate only a part of the processes of this kind which are known to take place in vegetables. We can change wood into starch, and starch into gum,

* This process might probably be usefully employed in making sugar for domestic use; grape sugar of this kind would for many purposes form a substitute for that of the cane.

and gum into sugar; but chemistry is altogether unable to reverse the process, and convert sugar back again into wood.

The plasticity of these compounds of carbon and the elements of water, is not however limited to mutual transformations. By various kinds of *decomposition* they can be changed into other substances such as alcohol and vinegar. One of the most common changes of this kind is *fermentation*. When to a decoction of malt, or to the juices of sweet fruit, we add a little of any matter in a fermenting state (yeast for instance), carbonic acid begins to escape, and in time the grape sugar contained in these liquids is found to be changed into *alcohol* or spirit. In this case

$$\left.\begin{array}{c}\text{Grape sugar, or}\\ C^{12}\,H^{12}\,O^{12}\end{array}\right\}\ \begin{array}{c}\text{is divided}\\ \text{into}\end{array}\ \left\{\begin{array}{l}2\ \text{Alcohol—}C^{8}\,H^{12}\,O^{4}\\ 4\ \text{Car. Acid—}C^{4}\,O^{8}\end{array}\right.$$

$$\overline{C^{12}\,H^{12}\,O^{12}}$$

The carbonic acid escapes from the fermenting liquid in bubbles, and the alcohol remains in the water. By further exposure to the air the alcohol thus produced absorbs a portion of oxygen from the atmosphere, and is changed into vinegar.

These artificial modes of transforming wood, starch and vinegar, though they may not show us exactly the ways in which those changes take place in plants, are sufficient to give an idea of some of the means by which they may be effected. We may now consider another class of bodies found in most plants, the acids.

§2. *Vegetable Acids.*

1. *Acetic Acid or Vinegar* is one of the most abundant. It is present in the juices of many plants, is produced in the germination of seeds, and by the fermentation of dead vegetable matter. The composition of vinegar is carbon 4, hydrogen 4, oxygen 4, so that like grape sugar it contains equal proportions of carbon and the elements of water.

In conformity with this similarity of composition, a solution of cane sugar with a little vinegar added to it, when exposed to the air for some time, becomes changed into a solution of vinegar.

2. *Tartaric Acid*—is composed of C^8 H^6 O^{12}, containing therefore proportionally more oxygen, and less hydrogen, than the acetic. It is contained in sorrel and in some berries, and, in combination with potash, abounds in the grape. The bitartarate of potash obtained from the latter fruit, is the well known cream of tartar.

3. *Citric or Lemon Acid*—differs little in composition from the last, (C^{12} H^8 O^{14}). It gives acidity to the lemon, orange, cranberry, and strawberry.

4 *Malic Acid*—differs slightly in composition from the tartaric. It is C^8 H^6 O^{10}. It gives their sourness to the unripe apple and plum.

5. *Oxalic Acid*—is found abundantly in many plants, usually in combination with lime or potash. It exists in the sorrels, in rhubarb, and plentifully in many of the lichens which grow on trees and stones. Oxalic acid consists of carbon, hydrogen, and oxygen, in the proportion of C^4 H^2 O^8.

These and many other acids occur in greater or less abundance in most plants; and though they do not constitute an important part of their bulk, they are of some consequence. They communicate to many fruits and other articles of food an agreeable acidity. They combine with and render soluble and otherwise suitable for plants, many of the earthy substances which are found in them. They serve, in the modes before noticed, to effect changes in the substances contained in the tissues or sap; for example, in converting starch into sugar. And lastly, they are themselves capable of being transformed into various useful products, as we often see to be the case in the conversion of a sour unripe fruit into a sweet ripe one. In this change the acid present in superabundant quantity in the unripe fruit, and causing it to be unpalatable and unwholesome, is converted into grape sugar, and the fruit is thus rendered agreeable to the taste, and nutritive.

§3. *Nitrogenised Substances.*

These, though present in much smaller quantity than the non-nitrogenised constituents of the plant, are of vast importance both to the plants themselves and to the animals which feed on them. In the plant they appear to determine all the vital changes by which the other substances are produced; and to the animal they are the materials out of which alone its most important tissues can be formed.

1st. If we take a small quantity of the dough of wheaten flour and wash it on a linen or muslin rag so as to remove the starch which forms a large constituent of the flour, we find remaining on the cloth a substance of a remarkably sticky and tenacious character. It is known as the *gluten* of wheat, and it is to this substance that the flour owes its capacity for constituting a tenacious paste and for forming raised bread. It is a nitrogenised substance, insoluble in water, but soluble in acids and alkalies; and is similar in composition with the flesh of animals. It constitutes from ten to twenty per cent. of the grain of wheat. Other grains contain this substance, but in less quantity than that of wheat.

2nd. In Indian corn a similar substance, or rather a modification of the same, occurs, and has been called *Zein*. Another similar substance occurs in considerable quantity in peas and beans, and is named *Legumin*.

3rd. If the juices of many succulent plants, as of the tubers of the potato, are heated to the boiling point, flakes of curdled matter separate from the fluid, and are found to consist of the substance *albumen*, with which we are familiar in the white of egg. This substance may be regarded as chemically identical with gluten, but it differs in being soluble in water, though it curdles and becomes insoluble when heated. It is thus suited for circulating in the sap of plants; and as glutinous and albuminous matters seem to be mutually convertible, they may be regarded as related to each other in the same manner in which starch is related to sugar or gum.

All of the above mentioned nitrogenised substances contain, in addition to carbon, hydrogen, oxygen and nitrogen, a small portion of sulphur, which seems to be a necessary ingredient in their composition.

The following table from Norton shows the proportion of nitrogenised substances contained in several of the most important grains and roots:

	Wheat.	Oats.	Rye.	Indian Corn.	Peas.	Potatoes.	Turnips.
Water.......	15	16	12	12	14	75	86
Starch......	42	·38	40	40	42	15	7*
Gum & sugar	9	7	14	6	6	2	2
Nitrogenised subtances..	15	16	13	17	24	2	1½
Oil.........	2	6	3	9	2	½	½
Woody fibre .	15	15	16	14	9	4	2
Ashes.......	2	2	2	2	3	1	1
	100	100	100	100	100	100	100

In this table the quantity of nitrogenised matter expresses very nearly the flesh-producing value of the several substances when used as articles of food; and in this respect such facts are not only important in relation to the nature of plants, but in relation also to their use as food for men and animals. All the edible substances afforded by the vegetable kingdom may be grouped under two heads—the heat-producing and the flesh-producing. Under the former come starch, sugar, gum, and oil. These substances, by their combustion in the body, keep up animal heat, and prevent waste and thinness. Animals fed on such substances and not exposed to cold, tend to accumulate fat; on the other hand, the consumption of such food enables them to endure cold. To the second class belong gluten, albumen and legumin, which afford the material

* Pectin, a substance allied to gum, occurs here instead of starch.

of flesh and sinew. The scientific selection of food for animals depends in great part on the study of the relative amounts of these two kinds of food in different substances, and in duly proportioning these accordingly. The relative amounts of curd and cream produced by milch cattle may also be influenced in the same way. But these are subjects too extensive to be considered in this place.

We may close this notice of the organic matters contained in plants by stating briefly the relations which they bear to the food and structure previously referred to.

§4. *Conclusions as to the Food of Plants.*

The organic food of plants consists in part of gaseous or aeriform substances, and in part of substances not aeriform, or fixed. The gaseous part of the food may be absorbed by the leaves directly from the air, or by the roots from the soil; in which latter case it is usually taken up through the medium of water, in which it has become dissolved. The fixed part of the food can be obtained only from the soil, and only by the roots, and by these only in a state of solution in water. Of the elements actually found in the plant, those that constitute its organic or combustible part may be obtained either in a gaseous or fixed state, either from the air or from the soil; those that constitute its ashes or incombustible part, as we shall find, only from the soil.

In respect to both of these classes of substances, the root and the soil are the most important practical subjects of consideration; since the air is alike or nearly so at all times in its composition, and cannot in this respect be regulated by the farmer. Still, as the leaves absorb food from the air, whatever gives it the largest amount of healthy leaf will enable the plant to do this most effectually, and sufficient exposure to air and light are also absolutely necessary. The farmer, by taking proper care of the root and the soil, thus provides also for the proper action of the leaf and the air.

In respect to the particular elements of the organic part

of the food of plants, while it is useful to have in the soil organic matters yielding carbonic acid, it is more essential to have substances yielding nitrogen either as ammonia or nitric acid. For this reason the richer animal manures are justly held to be of great importance in agriculture; while it is also of the first importance that such manures should be applied to plants in their young state, that they may form large and healthy leaves and roots, and may thus be able to avail themselves of the stores of carbonic acid and ammonia afforded by nature. It is thus to be observed that while the organic part of the food of ordinary plants may be furnished by the air and rain, yet the more important cultivated plants require more than this in order that they may yield large crops; and further, that the small and starveling plants of a poor soil have not sufficient root or leaf freely to avail themselves of the liberal stores of nature. Hence, though strictly organic manures may not be so important to plants as those which supply the material of the inorganic part, they are still of great value.

CHAPTER VIII.

THE ASHES OF PLANTS.

§1. *Composition of the Ashes.*

We have already seen that the combustible or organic part of the plant, at least in the kinds cultivated by the farmer, largely preponderates over the ashes. We are not on that account, however, to suppose the materials of the ashes of small consequence to the plant; on the contrary, experience proves that they are of the utmost importance; and since they can be obtained only from the soil, and not at all from the air, their presence in the ground must be closely connected with its fertility or barrenness. The following table, from Norton, representing the results of chemical analyses of the ashes of plants, will enable us to illustrate these points.

*Table of the composition of the ashes of several cultivated plants.**

	Indian Corn	Wheat.	Wheat Straw.	Rye.	Oats.	Potatoes.	Turnips.	Hay.
Potash.............	23.2	29.5	7.2	32.8	27.2	51.5	42.0	18.2
Soda...............	3.8	trace	0.3	4.4		trace	5.2	2.3
Lime...............	0.1	2.9	8.5	2.9	4.9	1.8	13.6	22.9
Magnesia..........	17.5	15.9	5.0	10.1	9.9	5.4	5.3	5.7
Oxides of Iron and Manganese.......	0.1	trace	1.0	0.8	0.4	0.5	1.3	1.7
Silica..............	0.8	1.3	67.6	0.2	2.7	8.6	7.9	37.9
Chlorine...........	0.3	trace	0.6	......	0.3	2.7	3.5	2.6
Sulphuric Acid.....	0.5	1.0	1.0	1.5	10.5	7.1	13.6	2.7
Phosphoric Acid...	49.2	47.0	3.1	47.3	43.8	11.3	7.6	6.0
Carbonic Acid.....	trace	......	......	......	......	10.4	......	.....
Charcoal in Ash, and loss	4.5	2.4	5.7	......	0.3	0.7	......	.....
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* The teacher should copy this table on a large scale, and attach it to the wall of the school-room. The pupils may copy it on their slates, and should be prepared to answer questions as to the properties and sources of the substances, and the proportions in which they occur in different plants. Much time may be profitably spent in this exercise.

The substances in this table may be shortly described as follows:

1. Two of them, *Potash* and *Soda*, are alkalies, that is they are highly soluble in water, have a caustic and alkaline taste, combine with acids to form salts, and with oils to form soaps; change vegetable blue to green, and yellow to brown; and tend, when strong and pure, to corrode animal and vegetable substances. Potash is a compound of the metal potassium with oxygen; soda is a compound of the metal sodium with oxygen. For uses in the arts, potash is obtained principally from the ashes of wood, but the ashes of all land plants contain it. The common potash of commerce, as obtained from wood ashes, is not pure, but a compound of the substance with carbonic acid. Common nitre or saltpetre is a compound of potash with nitric acid. It is named the nitrate of potash, and may serve as an example of the salts of potash. Soda is commonly obtained from sea salt, which is a chloride of sodium, or from the ashes of sea weeds and sea-side plants. The common washing soda is a compound with carbonic acid; and with an additional dose of that substance, soda forms the bi-carbonate of soda used for effervescing draughts. The nitrate of soda is a salt similar in some respects to saltpetre, and extensively used in agriculture. The sulphate of soda is common Glauber's salt. Sea salt, a compound of the metal sodium with chlorine, is the most abundant of all the natural sources of this substance.

2. Two other substances in the table are alkaline earths,—*Lime* and *Magnesia*. Their chemical properties are somewhat similar to those of the alkalies, but they are less soluble in water, both in their pure state and when in combination with carbonic acid. Hence they are less active in the manifestation of their alkaline powers. Lime exists very abundantly in nature as carbonate of lime, which forms marble, limestone and chalk, and occurs in marl, in soils, in the shells of aquatic animals, and in the ashes of plants. When carbonate of lime is exposed to a red heat, it loses its carbonic acid, and quick or caustic lime

remains. Gypsum or Plaster of Paris is the sulphate of lime. Lime is a compound of the metal calcium with oxygen. Magnesia is less abundant than lime, but occurs with it in dolomites or magnesian limestones, and in soils. The medicine Epsom salt is sulphate of magnesia. The calcined magnesia of the shops is this earth uncombined. Magnesia is a compound of the metal magnesium with oxygen.

3. Two other substances in our table are ordinary metallic oxides, the *oxide of iron* and the *oxide of manganese.* The common metal iron every one knows; and when on exposure to air and moisture it rusts, it combines with oxygen and constitutes an oxide known as the peroxide of iron, of which the yellow or brown rust of iron and red ochre are examples. This substance occurs in most soils, and gives to them a reddish or brownish color. There is another oxide of iron, the protoxide, having less oxygen, which occurs in some wet soils and bog waters. It has a greenish or greyish color, and when exposed to air passes into the peroxide. Common green vitriol is the sulphate of the protoxide of iron. The oxides of iron occur in very small quantity in the ashes of plants.

Oxide of manganese occurs in still smaller quantity, and is sometimes absent. It is hence not supposed to be essential to their healthy growth.

4. The next substance in our list is *Silica*, an oxide of the element silicon. Silica is one of the most abundant substances in nature—common flint, sand, and rock crystal are examples of it. It generally constitutes the far greater part of the bulk of the soil. Though silica in itself is quite insoluble and infusible, yet in combination with alkalies and alkaline earths, it forms silicates which are fusible in the heat, and some of them quite soluble in water. In this form it enters into the roots of plants, and in some of them, especially in the grains and grasses, appears in large quantity. The silicates of potash and soda are specially important to plants in this respect.

5. *Chlorine*, the next substance in the table, is very different from the last substance. It is an element, and

when pure is an air or gas heavier than common air, of a greenish color, and is suffocating and irritating when inhaled. It rapidly decomposes certain organic compounds, combining with the hydrogen of them to form an acid known as hydrochloric acid. Hence it is used to decompose offensive odours in the air, or as a disinfectant, and to decompose coloring matters in fabrics, or as a bleaching material. In the ashes of plants it does not occur pure, but in combination with soda or its metallic base sodium, constituting chloride of sodium or common salt, a substance of vast importance to the health both of plants and animals.

6. The two next substances in our table, *Sulphuric Acid* and *Phosphoric Acid*, are called acids as having a sour taste, the property of reddening vegetable blues, and of combining with alkalies and similar substances to form salts. Sulphuric acid or oil of vitriol, is a compound of sulphur and oxygen. In the ashes of plants it occurs in combination with lime and potash. Phosphoric acid is a compound of phosphorus and oxygen. In connection with lime it forms phosphate of lime or bone earth, one of the most important substances in nature, since of it the bones of animals are composed; and the plants on which these animals feed must contain it in order to afford nourishment to their bones. It is also a substance present in comparatively small proportion in soils, and hence one that deserves the most careful study of the agriculturist in regard to its preservation and supply.

The last lines of the table represent carbonic acid, which we have already considered, unconsumed charcoal and loss in the processes of analyses; so that we have in all nine, or, including the oxide of manganese, ten distinct substances which require attention in considering the ashes and the inorganic food of plants.

§2. *Uses of the Ashes.*

There are certain general statements in relation to these substances, which lie at the very basis of scientific agriculture, and should be firmly fixed in the mind of the farmer.

1. The substances found in the ashes of plants are not present accidentally, but are absolutely essential to the life and health of the plant. In every soil, and in every climate, a plant of wheat will be found to contain in its ashes all the substances mentioned in the table, and if deprived of any one of them it cannot thrive.

2. Different plants and different parts of the same plant contain the materials of the ashes in different proportions. For example, in the ashes of the potato, potash largely predominates; in those of wheat, silica and phosphoric acid; and in the wheat plant, while silica is the leading ingredient in the ashes of the straw, phosphoric acid prevails in the ashes of the grain.

It is to be observed here that substances very similar to each other in properties may sometimes to a certain extent be substituted the one for the other. Thus, in default of potash, soda may be used to some extent instead. Different varieties of the same species of plant also differ somewhat in their proportions of ash. But with these limitations, the law is invariable that every plant must have its own special proportions of these materials.

3. The absolute quantity of ashes is different in different plants, and in different parts of the same plant, and also in different stages of growth of the same part. Thus wood rarely contains more than from 1 to 2 per cent. of ashes, while hay may give 6 to 14 per cent. The straw of wheat contains 6 per cent. or more, the grain only 1 to 2 per cent. The young leaves of trees have little ashes, the old leaves a very large quantity.

4. The substances contained in the ashes can be obtained by the plant only from the soil, or from the manure which the farmer places therein. They cannot be obtained in any degree like the materials of the organic part from the air. Further, in every crop the farmer necessarily removes a large quantity of these ash materials from the soil; and unless the latter be found, when we come to consider its composition, to contain these in unlimited quantity, it follows that cropping must exhaust the soil of the inorganic food of plants.

These truths in relation to the inorganic constituents of the plant, are among the most valuable results of modern chemistry in its application to agriculture, and must be borne in mind in all our subsequent studies of the subject.

If we ask why these ash ingredients are so important, it is probable that a full and complete answer cannot yet be given. It may be stated however, that they are useful mechanically and chemically. Mechanically, some of them, like the silica in the straw of wheat, may serve to give strength and protection. Chemically, others may aid the plant in the production of its organic part. This last is by far the more important use, and deserves some detailed consideration before we advance further.

The absorption by plants into their system of earthy matters constituting their ashes, appears to bear a direct relation to the power of forming those non-nitrogenised substances of which the greater part of the fabric of plants consists. This might be inferred from the intimate union of the ashes with the woody matter, and also from the denser and harder woods yielding much ash; but it is also confirmed by experiments, especially by those of Boussaingault. It would seem that when plants are deprived of supplies of earthy matter the leaves do not possess the power of decomposing carbonic acid, and forming woody and similar substances.

It would also seem that certain earthy matters are specially related to certain kinds of non-nitrogenised matter—for example, that all plants which produce much starch, sugar, or gum, require much potash. It is also to be observed that in some species of plants a much less proportion of earthy matter suffices to enable growth to go on than in others. Hence the well known fact that the growth of one kind of plant on a certain portion of soil does not prove its fitness for the growth of other kinds of plants. A fir tree may thrive on soil quite too poor in alkalies and other earthy matters for the healthy growth of a maple tree.

With regard to the nitrogenised constituents of the plant, as gluten and albumen, it would seem that the

presence of sulphates and phosphates is of especial importance to them. The former afford the sulphur which these nitrogenized substances contain, and phosphates are always plentiful in the ashes of those parts of plants which are rich in nitrogen.

The proportions of the several kinds of earthy matter required by plants are also sensibly different, as well as the gross quantities. This is readily seen by a glance at the table, which shows that the ashes of one plant may contain as much potash as all or nearly all the other substances; another as much lime, another as much silica. The power of selecting these substances appears, in the healthy state of the plant, to reside mainly in the root, but the action of the root in this respect is determined by the requirements of the plant and the changes going on in all its parts. Hence the requirements of the same plant may not be the same in different stages of growth.

CHAPTER IX.

THE SOIL.

§1. *Nature and Origin of the Soil.*

The soil is derived from the waste of the rocks of the earth's crust; but it is not a mere mass of rubbish; on the contrary, it is a complex mixture of a number of substances in which many interesting chemical changes are constantly going on, and which possesses many important properties in reference to the nutrition of the plants that grow on it.

With regard to the origin of soils from rocks, we may take as an example the common and durable rock granite. In a piece of granite we can usually perceive three distinct minerals: 1st, quartz or flint, which is nearly pure silica; 2nd, feldspar, with flat and shining surfaces of a white or reddish colour, and usually the largest ingredient in the mass. It is a compound of silica with alumina and potash, or soda, or both; 3rd, mica, black or silvery scales with metallic lustre, and composed of silica, alumina, oxide of iron, oxide of manganese, potash, and sometimes magnesia.*

Now a mass of such granite is slowly acted on by the weather; that is, by the rain-water charged with carbonic acid. The latter substance gradually decomposes the feldspar, removing its potash and soda, and leaving the silica and alumina, which then become soft and crumbling, and ultimately fall into fine clay. The feldspar being thus

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* If the teacher can obtain a piece of granite, these minerals may be easily shown to the pupils. The allied rock syenite has the mineral hornblende instead of mica. Hornblende is usually of a blackish colour, and consists principally of silica, magnesia, lime, and oxide of iron.

broken up, the quartz and mica fall asunder into sand and flat scales, and a soil results, which in its texture will be partly of a sandy and partly of a clayey nature, and as to composition will contain silica, alumina, soda, potash, oxide of iron, and perhaps carbonate of lime, phosphate of lime, and other substances contained in the minerals which may be mixed with the granite. These substances will be in the state of clay, which has the power of retaining the more soluble matters in its pores, or in the state of grains of sand, which may be themselves gradually undergoing waste, and yielding their ingredients to the soil.

Let now a mass of such soil be acted on by water, and the clay may be washed away in whole or in part, and deposited in valleys and flats, giving rise to a stiff soil. The sand may remain or be washed into some other place, and will constitute a sandy or light soil, and there may of course be any number of mixtures of these two opposite kinds.

Further, let plants grow on this soil, and their roots and fallen leaves decay in and upon it, and a certain quantity of vegetable mould will be produced, and mixed with the soil, constituting its organic part.

It will be observed that these statements refer to a granitic soil only, but in the case of other rocks the process is similar; though it is evident that the greater the variety of the rocks and minerals ground up to form the soil, the more complex will be its composition. Still as the common rocks are everywhere composed of a few elements, it follows that in the main the soils of all parts of the world are alike, differing principally in the *proportions* of the not very numerous substances of which they are composed.

Such being the origin of the soil, it is evident that, regarding it from different points of view, we may for practical purposes form different classifications or arrangements of soils. Let us next consider these.

§2. *Arrangement of Soils according to Mechanical Texture.*

We may regard soils as more or less coarse or fine, and thus obtain a classification depending on the mechanical

texture of the soil, which, for practical purposes, is much used and of great value. In this respect the soil may vary from coarse pebbles or loose sand to the finest and most tenacious clay; and in general, those soils are best adapted for agriculture which consist of mixtures of sand with a moderate quantity of clay and a little vegetable matter. When sand or other coarse matter predominates, the soil is deficient in the power of retaining water and the soluble and volatile parts of manure. When clay is in excess, the soil is too retentive of water, is not easily warmed, does not admit of access of air, and consequently does not allow those chemical changes to take place in the soil and manures placed in it, which are necessary to prepare proper food for plants. The following classification of soils in reference to these points is proposed by Professor Johnston:

1. *Pure Clay;* from this no sand can be extracted by washing.
2. *Strong Clay*, or brick clay, contains from 5 to 20 per cent. sand.
3. *Clay Loam*, has from 20 to 40 per cent. sand.
4. *Loam* has from 40 to 70 per cent. sand.
5. *Sandy Loam* has from 70 to 90 per cent. sand.
6. *Light Sand* has less than 10 per cent. clay.

§3. *Arrangement of soils according to their general chemical characters.*

We may classify soils according to their predominant or leading ingredients. Here we may divide soils into organic and inorganic parts, the former consisting of the remains of plants and animals mixed with the soil, the latter of the mineral substances originally present in it. These last again may consist of silica, alumina, or lime in predominant quantity. Hence we obtain such a classification as the following:—

1. *Organic soils*, or those of bogs, and the vegetable mould of the woods, consisting in great part of partially decomposed vegetable matter.

2. *Silicious soils*, or those in which silicious sand is the prevailing ingredient, and which are often formed from the waste of sandstone rocks.

3. *Argillaceous soils*, or those which consist principally of clay, and are often formed from the waste of slates and shales.

4. *Calcareous soils*, or those in which lime is a principal ingredient, and which may be produced from the waste of limestone, chalk, or marl.

§4. *Arrangement of soils according to details of composition and relative fertility.*

We may classify soils of any or all the kinds separated in the above heads, according to their fertility or barrenness in relation to our cultivated crops, that is, according to the presence or absence of the materials of the ashes of those crops. No soil, unless it contains some substance poisonous to plants, is absolutely barren; but we call a soil barren which will not produce such plants as the farmer cultivates. Such a soil may be made fertile by adding to it the substances in which it is deficient; but if this cannot be done except at a cost as great or greater than that for which fertile soil can be procured, the soil may be regarded as practically barren and worthless.

The mechanical texture and predominant ingredients of soils, though important to their fertility, do not absolutely determine it. A sandy, loamy or clay soil, or a silicious or calcareous soil may or may not contain all the materials of the ashes of our crops; and if it does not it will be barren. This obliges us to consider the composition of soils in detail. Bearing in mind then the three classifications of soils above explained, let us next proceed to consider their composition.

This will be seen at a glance in the following table, from Johnston, representing the ingredients of three different soils, with their relative properties.

Composition of soils of different degrees of fertility.

	Fertile without Manure.	Fertile with Manure.	Barren.
Organic matter,	97	50	40
Silica (in the sand and clay,)	648	833	778
Alumina (in the clay,)	57	51	91
Lime,	59	18	4
Magnesia,	8½	8	1
Oxide of iron,	61	30	81
Oxide of manganese,	1	3	½
Potash,	2	trace	trace
Soda, } chiefly as common salt	4		
Chlorine, } chiefly as common salt	2		
Sulphuric acid,	2	¾	
Phosphoric acid,	4½	1¾	
Carbonic acid, (combined with the lime and magnesia,)	40	4½	
Loss,	14	....	4½
	1000	1000	1000

§5. *Causes of Fertility and Barrenness.*

In considering this table, it is apparent that the fertile soil contains all the substances present in the ashes of plants, while the soil fertile with manure is deficient in some of them, which can however be supplied in the ordinary course of agriculture. The barren soil on the other hand is destitute of so many of the most important of these substances, that it can scarcely be rendered fertile.

We also find that, even in the fertile soil, the constituents of the ashes of plants are present in very different proportions from those in which they occur in the plant; some of those most abundant in the plant being the rarest in the soil, and *vice versa*. Hence the mass of the soil is to be regarded not as in itself food for plants, but only as holding and containing this food, and giving support and protection to the plant and its roots. The substance alumina, which we find

in the soil and not in the plant, is especially important in these ways.

We thus learn that it is possible to reduce a fertile soil to barrenness without materially altering its weight, bulk, or mechanical texture. More precisely, we find that the substances necessary to the plant, and present in smallest quantity in the fertile soil, and absent from the more barren ones, are potash and soda, chlorine, sulphuric acid, and phosphoric acid. Of these, potash and phosphoric acid are both the most important to the more valuable crops, and the most difficult and costly to procure.

It results that in so far as inorganic matters are concerned, the *alkalies* and *bone earth* stand first as of practical importance in the theory of agriculture. We could, by adding to the soil in the second table sufficient quantities of bone earth, potash, soda, gypsum, and common salt, remedy most of its deficiencies. Further, since a small percentage in the table amounts to a large quantity in the soil of an acre of land, the quantity of these substances present in the fertile soil may be sufficient for many crops, and that required by the more barren soil for even one crop may be very considerable.

We must also consider here the differences of the *soil* and *sub-soil*. The upper soil may be fertile and the sub-soil barren, and *vice versa*. In the former case, crops which spread their roots near the surface, as is the case with the grain crops, will thrive on it, but will exhaust it more rapidly than if the sub-soil were fertile. In the latter case, only plants which can send their roots deeply into the soil will succeed well. In the former case, mixing the sub-soil with the soil may be injurious, in the latter it may be beneficial.

Again our table shows that the fertility or barrenness of soils does not altogether depend on the quantity of organic matter, that is of vegetable mould or humus present in the soil. This is no doubt of great value. It is constantly yielding by its decay, carbonic acid and ammonia to nourish the organic part of the plant. It is setting free, little by little, the earthy matters of its own ashes. It is also by its decay inducing chemical changes, which tend to set free

other matters held in combination in the particles of the soil. It renders clay soils more friable, and sandy soils more retentive of volatile substances, and of substances in solution. It darkens the colour of the soil, and thus enables the solar heat to have more effect on it. These are all important uses. Still there are some alluvial soils nearly destitute of organic matter, and yet of almost inexhaustible fertility, and there are some peaty soils very rich in organic matter, yet very barren. Important though the organic matter of the soil is, the mineral matter is more so.

The table of the composition of soils, when compared with that of the ashes of cultivated plants, throws light on the causes of *exhaustion of soils*, and on the advantages of *rotation of crops*. Soils manifestly become exhausted when, by a succession of crops requiring much of some particular substance, that substance is removed from the soil to such an extent that the crop can no longer obtain a sufficient quantity; and the number of crops which a soil will give, depends on the amount of such matter which it originally contained. The particular substance first exhausted will be that which was originally most deficient in the soil, and on which the crop in question makes the greatest demands. Further, the exhaustion of one substance is fatal to the fertility of the soil, especially for such crops as require much of that substance, since the plant cannot, except within very narrow limits, substitute one element for another. Again, in reference to rotation, it is plain that a soil may be exhausted for one plant, when it still retains food for another. A plant requiring much ashes may thus alternate with one requiring little; a plant requiring much silica and phosphoric acid, with one requiring much alkali or lime; a plant feeding mainly on the surface with one feeding mainly on the subsoil. Of course, that rotation may be of permanent service, it is necessary that advantage be taken of the change of crop to restore the substances exhausted in former years.

Our table also enables us to understand the uses of *special manures* and *mineral manures*. If a soil is deficient in sulphuric acid, and contains all the other requisites

of fertility, then gypsum (sulphate of lime) will be the special manure that it requires; but if it has enough of sulphuric acid and is deficient in phosphoric acid, then gypsum will do no good, but bone earth will produce or restore fertility. Again, after a heavy dressing of one of these substances, it may not be required for several years, but some other substances may be needed; and this all the more because the larger crops will exhaust such other substances more rapidly than the smaller crops did previously. It is evident that to apply such special and mineral manures with economy and success, requires much knowledge, and that the application useful on one soil may be quite useless on another, and the application useful on a soil in one season useless in another. In no point do practical men, who make experiments with mineral manures, err more widely than in this. Such errors can be best avoided either by having an accurate analysis of the soil, by making small experiments with special manures, or by comparing the composition of the plants which fail or succeed on the land in question, and inferring from this the substances deficient.

Lastly, this subject connects itself with the differences of good and bad seasons, and with many diseases of cultivated crops, which at first sight do not appear to depend on the soil. The farmer whose land is becoming exhausted, often deceives himself by supposing that there has been a succession of unfavorable seasons, or that the seasons are becoming worse. His land may be in such a state that in an unusually favorable season it will produce a good crop, but not in an ordinary season, and since the large crop exhausts it more than the small one, it may be even worse than usual in the following year. Now, to be profitably cultivated, the land should be in such a state of fertility that it will yield good crops in ordinary years, and that failures should be the exception, not the rule. It is also not unfrequently the case that the unhealthy condition of a plant, depending on deficient nutriment from the soil, is the predisposing cause of diseases and failures. If the soil has the materials of the straw and leaves of wheat, and has not the phos-

phates required for the grain, the latter cannot be produced; but in this case it usually happens that the plant does not simply wither without producing grain, but that, unable to turn the stores of sugar and albumen it has accumulated to this use, these become a prey to the fungi, which cause rust, mildew, and other diseases; and the loss of the crop is attributed to these, when the primary cause was a partially exhausted condition of the soil. In such a case it is even possible that the straw may be luxuriant without the plant having the means to perfect its seed.

These considerations embrace all the essential points relating to the soil, which can be deduced from its composition; but one most important question remains, which cannot be answered by chemical analysis alone. This is, to what extent are the substances present in the soil *practically available* for the use of plants? On the one hand the nutritive substances contained in the soil might be in a state so soluble that they might be exhausted in a single season. On the other hand, chemical analysis may, and, no doubt, often does, shew the presence in the soil of nutritive substances which are in a state so insoluble that they cannot be obtained by the roots of plants within the time to which they are restricted for their growth. Theory and experience concur in proving that soils differ very much in these respects, and that while all soils have considerable power of retaining in their pores even the most soluble substances, some part with them too readily, and others retain them too firmly, or only part with them when exposed to various preparatory processes. The management of the soil with reference to the use and retention of nutritive substances is one of the most difficult problems, both for the chemist and the practical farmer.

§6. *Absorbent or retaining power of the soil.*

The absorbent and retaining power of soil is one of its most remarkable properties; and much additional prominence has been given to it by recent experiments

detailed by Baron Liebig in his late work on "The Natural Laws of Husbandry." The arable soil is not a mere sieve through which any matter in solution can pass freely; but, on the contrary, it has a great power of retaining, as in a filter, all saline and other substances that may be present in the water permeating it. This power is very different in different soils, and in the same soil in the case of different substances. In passing through any ordinary soil the dark water of a dunghill, or a saline solution, will lose large portions of its contents, which remain, so to speak, entangled among the particles of the soil, or adhering to their surfaces. In light and sandy soils this power of retaining nutritive substances is less; in heavier soils, greater; in soils having much vegetable matter it is strongly marked; and in light soils of a red or brown color, having the particles mixed with oxide of iron, it is greater than in colorless sandy soils. Extremely light sands, and extremely compact clays, possess this power in the smallest degree, so that the porosity of the soil seems to be mainly important in reference to this property.

Further, the absorptive property of the soil appears to be connected with a chemical action upon the substances present in it; some solutions being decomposed in passing through certain soils, and one substance retained while another is allowed to pass. Thus salts of potash and ammonia are found to part with these bases to the soil: the acids present entering into other combinations.

It would seem from various experiments that the matters thus absorbed by the soil are more readily available to plants than those in chemical combination with its ingredients. The latter are only little by little set free by decomposition; and this is believed to explain the fact that chemical analysis often shews a larger amount of nutritive substances than experiment proves to be practically available, and also the effect of tillage in improving soils. Thus, if an analysis shows a large quantity of phosphate of lime in a soil, it may yet happen that plants like wheat, which require much of this substance, may not be able to obtain it in time, in consequence of its occurrence in the

form of solid particles or sand. Tillage, by stirring the soil and promoting the solution of these particles and their mechanical absorption by the ground, may make them readily available; and may consequently appear to enrich the soil. The presence of organic matter in the soil has a double influence in these processes. First, by producing carbonic acid, it adds to the solvent power of the water of the soil. Secondly, by its mechanical absorbing power, it retains the substances dissolved till required by the roots of the crop.

Certain chemical manures also, as common salt and lime, are highly important in the solution of inert substances; and the matters thus dissolved, being absorbed by the soil, are retained for use.

This property of soils is of immense importance in the formation of composts, and the use of bog earth under manure heaps and stables. The earth and bog become mechanically saturated with nutritive matters, and thus become most valuable fertilisers.

The absorbent power of soils also serves to illustrate the advantages of subsoil ploughing and draining, as it is of the highest importance to bring all parts of the soil within reach of the air and water permeating it, and that it may absorb nutritive matters instead of rejecting them from its surface. Were it not for this property, soluble substances present in the soil would be immediately washed out of it, and fallowing, tillage and draining would rapidly impoverish the land by allowing its soluble constituents to be carried off by water.

It follows, from these considerations, that our estimate of the value of arable land must depend mainly on its richness in the ingredients of cultivated crops, on the availability of these ingredients, and on its power of absorbing and retaining the manures placed in it by the farmer, or produced by the decomposition of its own materials.

CHAPTER X.

EXHAUSTION OF THE SOIL.

§ 1. *Causes of Exhaustion.*

Johnston gives the following estimate of the quantity of matter taken from an acre by an ordinary English four course rotation. He supposes that the crop of turnips may amount to 25 tons, that of barley to 38 bushels, that of clover and grass to 2 tons per acre, and that of wheat to 25 bushels.

	Turnip roots	Barley.		Clover	Rye grass	Wheat.		Total.
		grain	straw			grain	straw	
Potash.........	145.5	5.6	4.5	45.0	28.5	3.3	0.6	239.0
Soda	64.3	5.8	1.1	12.0	9.0	3.5	0.9	96.6
Lime	45.8	2.1	12.9	63.0	16.5	1.5	7.2	149.0
Magnesia.......	15.5	3.6	1.8	7.5	2.0	1.5	1.0	32.9
Alumina	2.2	0.5	3.4	0.3	0.8	0.4	2.7	10.3
Silica..........	23.6	23.0	90.0	8.0	62.0	6.0	86.0	299.2
Sulphuric Acid..	49.0	1.2	2.8	10.0	8.0	0.8	1.0	72.8
Phosphoric Acid.	22.4	4.2	3.7	15.0	0.6	0.6	5.0	51.5
Chlorine	14.0	0.4	1.5	8.0	0.1	0.2	0.9	25.6

Total pounds 970.9

If we were to suppose the common four years' rotation of oats, turnips or other green crop, wheat and hay, the result would not be very materially different.

The table shows a loss by cropping in four years of rather less than half a ton of mineral matter from an acre; and if we inquire as to the nature of this loss, we find that

it might be repaired, if we except the silica, which, being abundant in nearly all soils, may be left out of the account, by the following quantities of mineral manures :

325 lbs dry Pearl Ash.	150 " Quick Lime.
333 " Carbonate of Soda.	200 " Epsom Salts.
43 " Common Salt.	83 " Alum.
30 " Gypsum.	210 " Bone dust.

These substances would be required to replace those taken away, provided that no part of the crops or the manure derived therefrom should be returned to the soil.

It will be observed that the green crop portion of the rotation carries off the greater part of the mineral substances, and consequently that grain crops are not the most exhausting to the soil. Practically however, the difference between a rotation such as this, and no rotation, includes the supposition that manures are introduced with the green crops, whereas where there is no rotation, grain crops are often cultivated for a succession of years without manure.

Whatever the crops cultivated, it is apparent that cropping for successive years without manuring, must ultimately exhaust the soil or render it barren. A very rich soil may long endure such cropping, owing to the great quantity of these substances contained in it; a poor soil will be reduced to sterility sooner; a shallow soil will fail sooner than a deep one, a light soil sooner than a stiff one.

Further, the more available substances in the soil will be exhausted first. The less soluble will remain, and thus a soil may become barren while it still retains much of the food of plants: in this state its productiveness may partially and temporarily be restored by leaving it at rest, and especially by fallowing and tillage, or by ploughing in of green crops, all of which processes tend to set free some of the previously insoluble substances.

If we compare the table of the substances removed by crops with that of the composition of the soil, it is apparent that the exhaustion falls most heavily on some of the substances least abundant in the soil. We cannot exhaust any ordinary soil of silica, alumina, or oxide of iron; nor can a soil naturally calcareous be exhausted of its lime;

but there are few soils which can bear several crops without manure and not suffer an appreciable exhaustion of their available phosphates and alkalies. This gives to these substances a very great importance as mineral manures.

It is observed in practice, especially on those virgin soils rich in vegetable mould, that long cropping deprives them almost entirely of this vegetable mould, and this is sometimes regarded as the sole cause of their impoverishment. In reality however it is only a small part of the cause; but it is to be observed that the vegetable mould contains within it a large amount of the material of the ashes of leaves and other vegetable matters which have grown upon the soil, and these are exhausted with the disappearance of the vegetable mould. It may even happen that the forests growing for ages on the soil have drawn up from it nearly its whole stores of available mineral matter and deposited these in the surface vegetable soil. In this case so soon as cropping has exhausted the black mould, the fertility of the soil is gone. But in soils of fertile character it is more usual that much mineral food for plants remains in the soil and subsoil, though often in a state which requires the action of the air for its reduction to a useful state; hence after the vegetable mould has been exhausted by destructive cropping, the land will still yield something after repose or fallowing, or subsoil or trench ploughing.

As the soil becomes gradually poorer under exhaustive cropping, the grain ordinarily becomes short in straw, and the kernel smaller in quantity and poorer in quality. At the same time certain weeds, which still find enough of food in the soil, grow with greater rankness than the crop. Various kinds of parasitic fungi, the mildews, rusts, &c., attack the crop and diminish still farther the yield. All these evils are aggravated if the same variety of grain is cultivated without change of seed. In these circumstances the uninstructed farmer usually holds that the seasons have become less favorable than formerly, and he is confirmed in this conclusion by finding that in some unusually favorable season he still has a fair crop. He is farther confirmed in it when he finds that ploughing in a green crop or adding

stable manure, though it increases the straw, does not much improve the grain or rid it of its diseases and enemies; and unless otherwise instructed than by his own experience, he may remain in ignorance of the fact that the ground is exhausted by the loss of the mineral matters he has taken from it in successive crops, and cannot be fertilized except by restoring them to it.

This sad picture of exhaustion applies to large portions of eastern America, and is the principal reason why the wheat culture continually recedes to the west, leaving the exhausted fields to be occupied with buckwheat or other inferior grains.

Some curious cases of special exhaustion of single substances have been observed by chemists. One of these is the removal of phosphates by pasturage. Pasturage is generally supposed to improve rather than to deteriorate the soil. Still the phosphates removed in the bones and milk of cattle, gradually tell on the quantity of these substances in the soil; and hence, in certain old pastures, beginning to fail, a dressing of bone dust has been found to produce almost magical effects, because it restored the one ingredient, in this case, beginning to be deficient.

It follows from the above statements, that to know the nature, causes and remedies of exhaustion in any particular case, we must study the original composition of the soil, the substances which have been removed from it by cropping, and the best and cheapest way of supplying those which have become deficient.

It also follows that the fertility of the land can be maintained only by restoring to it an adequate amount of the substances of which our crops deprive it, or by rendering fresh quantities of these still in the soil available to plants by tillage, fallowing, &c. This last mode however leads at length to a total exhaustion of the soil, if pursued without recourse to the other. Fortunately for the farmer, the produce which he must sell off the farm does not take away so much inorganic matter as that which he may keep; if for instance, he disposes only of grain and animal produce, he can keep for the sustenance of the land all the straw,

hay, roots, &c., or the manures produced in their use by animals. By a careful economy of these resources in a system of rotation farming, exhaustion may in rich lands be avoided for an indefinite period, though the introduction of additional manures will even in this case be more or less requisite. In China and Japan a scrupulous and painstaking economy of every kind of animal and vegetable manure has maintained the fertility of the soil from the most remote ages, and will continue to do so, and to support a dense population for an indefinite period, and this without any knowledge of scientific principles. On the other hand the neglect of manures in some districts of North America establishes a drain upon the land, which no amount of scientific knowledge can remedy except at very great cost.

§ 2.—*Exhausted Soils of Canada.*

Many very instructive facts in relation to the exhaustion of soils in Canada, are disclosed by the analyses of Canadian soils executed by Dr. Hunt, of the Geological Survey of Canada, and published in the Report of the Survey for the years 1849 and 1850, and also in the general Report, in 1863. We shall introduce here a few of these analyses in illustration of the general statements already made.

One of the soils analysed was a vegetable mould from the alluvial flats of the valley of the Thames in Western Canada, and is said to have yielded 40 or even 42 bushels of wheat to the acre, and in some instances, to have been successfully cropped for thirty or forty years without manuring. Dr. Hunt describes this soil as follows :—

"Such is the fertility of the soils in this region that but little need has hitherto been felt of a system of rotation in crops; some however have begun to adopt it, and have commenced the cultivation of clover, which grows finely, especially with a dressing of plaster, which is used to some extent.

"The natural growth of these lands is oak, and elm, with black walnut and whitewood trees of enormous size; the black walnut timber is already becoming a considerable

article of export. Fine groves of sugar maple are also met with, from which large quantities of sugar are annually made.

"I give here an analysis of a specimen of the black mould from the seventh lot of the first range of Raleigh. The mould here is eight or ten inches in thickness, and had been cleared of its wood, and used six or eight years for pasture; the specimen from a depth of six inches contained but a trace of white silicious sand.

"No. 1 consisted of—

Clay	83.4	
Vegetable matter	12.0	
Water	4.6	
		100.0

100 parts of it gave to heated Hydrochloric Acid—

Alumina	2.620
Oxyd of Iron and a little Oxyd of Manganese	5.660
Lime	1.500
Magnesia	1.060
Potash and Soda	.825
Phosphoric Acid	.400
Sulphuric Acid	.108
Soluble Silica	.290"

This, it will be observed, is a soil rich in alkalies, phosphoric acid, and soluble silica; and on these accounts, eminently adapted for the growth of wheat as well as of nearly all other ordinary crops.

With this may be compared a soil from Chambly, in Lower Canada, respecting which the following remarks are made:

"The soils of this Seigniory are principally of a reddish clay, which, when exposed to the air, readily falls down into a mellow granular soil. In the places where I had an opportunity of observing, it is underlaid at the depth of three or four feet by an exceedingly tenacious blue clay, which breaks into angular fragments, and resists the action of the weather. The upper clays constitute the wheat bearing soils, and were originally covered with a growth of maple, elm, and birch; distinguished from them by its

covering of soft woods, principally pine and tamarack, is a gravelly ridge, which near the church is met with about fourteen acres from the river; it is thickly strewn with gneiss and syenite boulders much worn and rounded. The soil is very light and stony, but yields good crops of maize and potatoes, by manuring."

"The extraordinary fertility of the clay is indicated by the fact that there are fields which have, as I was assured by the proprietors, yielded successive crops of wheat for thirty and forty years, without manure and almost without any alternation. They are now considered as exhausted, and incapable of yielding a return, unless carefully manured; and such, for the last fifteen or twenty years, have been the ravages of the Hessian fly upon the wheat, which is the staple crop, that the inducements to the improvement of their lands have been very small; so that the Richelieu valley, once the granary of the Lower Province, has for many years scarcely furnished any wheat for exportation. But the insect, which for the last three or four years has been gradually disappearing, was last season almost unknown, and the crops of wheat surpassed any for the last ten or twelve years."

"Of a number of soils collected at Chambly, only three have as yet been submitted to analysis; they are—one of the reddish clay taken from a depth of sixteen inches, from a field in good condition, and considered as identical in character with the surface soil before tillage, No. 2; and one at a depth of six inches, from a field closely adjoining, but exhausted by having yielded crops of wheat for many successive years without receiving any manure, No. 3; the latter supported a scanty growth of a short thin wiry grass, which is regarded as indicative of an impoverished soil, and known as *herbe à cheval;* both were from the farm of Mr. Bunker; the third, No. 4, is a specimen of the gravelly loam above mentioned, from an untilled field upon the farm of Mr. Yule."

No. 2 contained a small amount of silicious sand and traces of organic matter, and gave 5.5 per cent. of water.

100 parts of it yielded to heated Hydrochloric Acid:

Alumina	3.300
Oxyd of Iron	8.680
Manganese	.160
Lime	.711
Magnesia	2.310
Potash	.536
Soda	.340
Phosphoric Acid	.418
Sulphuric Acid	.020
Soluble Silica	.180

No. 3 consisted of—

Silicious sand with a little feldspar	9.0	
Clay	79.2	
Vegetable matter	6.8	
Water	5.0	
		100.0

100 parts of it gave—

Alumina	not determined
Oxyd of Iron	4.560
Lime	.347
Magnesia	.888
Potash, Soda	.380
Phosphoric Acid	.126
Sulphuric Acid	.031
Soluble Silica	.080

By the action of water, a solution containing minute traces of chloride and sulphates of lime, magnesia, and alkalies is obtained. 100 parts of the soil give in this way, of chlorine, .0013; sulphuric acid, .0005.

No. 4. This soil contained about 20 per cent. of pebbles, and 12 of coarse gravel; that portion which passed through the sieve consisted of—

Gravel	75.0	
Clay	13.7	
Vegetable matter	6.1	
Water	5.2	
		100.0

The soil was very red, and the sand silicious and quite ferruginous, consisting of the disintegrated syenitic rocks which make up the coarser portions.

100 parts gave—

Alumina	2.935
Oxyd of Iron	5.505
Lime	.156
Magnesia	.409
Potash	.109
Soda	.144
Phosphoric Acid	.220
Sulphuric Acid	.018
Soluble Silica	.080

The first of these soils, (No. 2) that which had not been hausted, closely resembles in its proportions of inorganic plant-food that first noticed. It is further to be observed, that while one of these soils, that from Raleigh, is very rich in vegetable matter, and the other, that from Chambly, contains very little, both are equally fertile as wheat soils. This is a striking evidence of the great importance of the mineral riches of the soil.

If now, we compare the fertile soil, No. 2, with the exhausted soil, No. 3, we see at once that the latter has parted with the greater part of its alkalies and phosphoric acid, and probably with the more available part of these substances. The exhaustion of potash, soda, and phosphates, is, in truth, the cause of its present sterility; and when we consider that the straw and grain of thirty crops of wheat have been taken from it without return, we have sufficient reason for the change.

The third soil, No. 4, characterised as of light quality, is, in comparison with No. 2, poor in lime, phosphates, alkalies, and soluble silica, but it has nearly twice as much phosphoric acid as the worn out soil, No. 4, and is not behind it in soluble silica. An equal quantity of ordinary manure would probably produce more effect on it than on the exhausted soil, No. 4.

Another term of comparison is afforded by a soil from the farm of Major Campbell, at St. Hilaire, which is said to have been reclaimed from comparative exhaustion, by manuring and draining. It is a heavy clay, and afforded, on analysis, in 100 parts:

Alumina	12.420
Oxyd of Iron	7.320
Lime	.697
Magnesia	1.490
Potash	.591
Soda	.231
Phosphoric Acid	.390
Sulphuric Acid	.022
Soluble Silica	.105

This soil, it will be observed, rises very nearly to the level of the unexhausted soil from Chambly; and the difference between it and the exhausted soil, No. 3, is, no doubt, due to the manures added by the proprietor, and to the admixture of unexhausted subsoil by draining and deeper ploughing.

That this last cause had some share in the result, is indicated by an analysis of subsoil, taken from the same field, but at a depth of thirty inches from the surface. No manures penetrate a clay soil to such a depth as this, so that this analysis gives the natural quality of the soil. It shows in 100 parts:

Alumina	4.380
Oxyd of Iron	6.245
Lime	.980
Magnesia	1.080
Potash	.753
Soda	.355
Phosphoric Acid	.474
Sulphuric Acid	.024
Soluble Silica	.210

It thus appears that the subsoil is far richer than the improved surface soil in alkalies, phosphates, and soluble silica. The subsoil is a vast store of mineral manure, ready to be applied to use by under-draining and subsoil ploughing. It would seem that this applies very generally to the exhausted clay soils of Canada, which, having been undrained, ploughed in a shallow manner, and cropped by plants which feed in these circumstances only on the surface soil, might be renovated by tile draining and the use of the subsoil plough more easily than by the application of manurial substances. This is a fact which holds forth a

gleam of hope for all the impoverished farms of the older and exhausted districts.

It is to be observed, however, that the material of the subsoil probably requires some tillage and aëration to make its constituents available for plants, so that it should be very gradually mixed with the surface soil. It would also require the addition of some organic matter, as, for instance, peat or bog mud.

In leaving these Canadian soils, it is deserving of remark, that even the richest of them are rather poor in sulphuric acid, and would, therefore, probably be benefited by the use of gypsum.

CHAPTER XI.

IMPROVEMENT OF THE SOIL.

This may be either mechanical, by acting on the texture of the soil and its relations to water and the air, or chemical, by adding to it nutritive substances. The former only will be considered in this place. The latter will come more naturally under the head of manures.

§ 1. *Tillage &c.*

Several methods of improving the mechanical condition of the soil are within the reach of the farmer.

One of these is the ancient and most important expedient of *tillage*. The stirring and loosening of the soil by the plough, the spade, the harrow, the subsoil plough, and other implements, are not merely necessary preparations for the seed, but important means of ameliorating the soil. The chemical changes proceeding in the soil, by which food is prepared for plants, require the presence both of air and water. The larger pores of the soil must be filled with air, the smaller with water. This is the condition of a mellow, well prepared soil. It is the condition most favourable to the germination of seeds and the penetration of roots, as well as to the complex chemistry of the soil itself. The roots of a crop exhaust the soil in their vicinity, while other portions remain untouched; but tillage mixes the whole again, and gives the roots of the succeeding crop a better opportunity of extracting nutriment.

Again, there are in most soils small fragments of vegetable and mineral matter, which, if exposed to the action of the air and moisture, would yield up their constituents as food for plants. Tillage enables them to do so. Hence

the maxim of some farmers that much and careful tillage is equivalent to manure. Hence also the benefit of fallowing, which not merely allows the soil to rest, but brings into use its reserve stores of nutriment.

We must, however, beware of supposing that tillage actually enriches the ground, or of falling into the error of those writers who maintain that nothing else is necessary to fertility. The manurial value, so to speak, of tillage, depends essentially on its power of rendering serviceable the insoluble portions of the soil; and when these are exhausted by a long course of cropping, tillage or fallowing will fail to be of service any longer in this respect. Even in this case, however, if the surface soil only is exhausted, subsoil and trench ploughing may bring a new soil within reach of plants, and by rendering its stores accessible, prolong for some time, though not for ever, the fruitfulness of the soil.

Subsoiling may be done either by the subsoil plough, contrived for the purpose, or by running a second plough in the furrow caused by another. In the former case the subsoil is merely stirred and broken; in the latter it is mixed with the soil, which may in some cases have a temporarily injurious effect. In either way, a few inches are added to the available depth of the soil, and this may be increased by a second or third subsoiling. Subsoil ploughing is of immense benefit when the surface has been run out by bad farming, and also in soils having a hard "pan" beneath the plough. I have known cases in which the subsoil plough has been the means of producing good crops from cold white sand and clay, previously very unproductive. In very wet and flat land, however, draining should go before or accompany subsoiling, otherwise an injurious wetness may result.

Another mode of improving the soil, is the addition of substances capable of changing its texture. Thus shore sand is sometimes carted upon stiff clays with benefit. In like manner coal-ashes, lime rubbish, sandy marl, peat composts, and many other substances ordinarily employed as manures, tend to lighten and pulverize the ground. On the other hand, marsh and creek mud, and similar sub-

stances, much improve the texture of light and gravelly soils, by making them more retentive. In applying manures containing much sandy and earthy matter, it is always to the interest of the farmer to consider the effects which they may have on the mechanical qualities of the soil, and to use them on those portions of ground where their effects in this respect will be most beneficial.

§ 2. *Draining.*

Another and most important mode of ameliorating the soil is under-draining, or draining by tiles and similar contrivances. No expedient has proved so serviceable in improving the mechanical qualities of the soil; and even in warm and dry climates like that of Canada, it has been found most profitable by all who have skilfully employed it.—Its various beneficial effects may be shortly summed up as follows:—

It makes the soil warmer, by draining off the water which otherwise would keep the ground cold by its evaporation. For this reason, it enables the ground to be worked earlier in spring and later in autumn, and renders the growth of crops more rapid.

It tends to prevent the surface from being too much washed by rain; as it enables the water to penetrate the soil, carrying downward the substance of rich manures, instead of washing it to lower levels. It thus, in connection with that absorbing power already described, saves the riches of the soil from waste.

It allows the roots of plants to penetrate deeply into the soil, instead of being stopped, as they often are, at the depth of a few inches, by a hard subsoil, or by ground saturated with water, or loaded with substances injurious to vegetation. For this reason, drained lands stand drought better than undrained, and their crops are also larger and more healthy. Hence also it often happens that draining benefits even light lands, if they happen to have an impermeable subsoil.

It permits free access of air, thus preventing the "souring" of the soil, and bringing manures of all kinds into a fit state for absorption by the roots.

It prevents injury to the soil from the water of springs and other waters coming from beneath by capillary attraction. It also prevents baking in dry weather, and causes the ground to crumble more freely when ploughed.

It tends to diminish the effect of frost in throwing out the roots of clover and grasses, by enabling the roots of these plants to take a deeper hold of the soil.

In short, it renders land easier and more pleasant to work; makes crops more sure and heavy; prevents alike injuries from drought and excessive moisture; economizes manures; and is equivalent to the deepening of the soil, and lengthening of the summer.

The following short summary of the methods of underdraining is taken from "Norton's Elements of Scientific Agriculture." It is to be hoped that its practice will soon be familiar to every farmer in our country.

"First, as to depth; where a fall can be obtained, this should be from 30 to 36 inches. The plants can then send their roots down, and find to this depth a soil free from hurtful substances. The roots of ordinary crops often go down three feet, when there is nothing unwholesome to prevent their descent. The farmer who has a soil available for his crops to such a depth, cannot exhaust it so soon as one where they have to depend on a few inches, or even a foot of surface. Manures, also, cannot easily sink down beyond the reach of plants. On such a soil, too, deep ploughing could be practised, without fear of disturbing the top of the drains. The farmer should not, by making his drains shallow, deprive himself of the power to use the subsoil plough, or other improved implements that may be invented, for the purpose of deepening the soil. There are districts in England, where drains have had to be taken up and relaid deeper, for this very reason. It would have been an actual saving, to have laid them deep enough at the first.

"Second, as to the way in which they should be made, and the materials to be used."

"The ditch should, of course, be wedge-shaped, for convenience of digging, and should be smooth on the bottom."

"Where stones are used, the proper width is about six inches at the bottom. Small stones should be selected, or large ones broken to about the size of a hen's egg, and the ditch filled in with these to a depth of nine or ten inches. The earth is apt to fall into the cavities among larger stones, and mice or rats makes their burrows there; in either case water finds its way from above, and washes in dirt and mud, soon causing the drain to choke. With small stones, choking from either of these causes cannot take place, if a good turf be laid, grass side down, above the stones, and the earth then trampled in hard. Cypress or cedar shavings are sometimes used, but are not quite so safe as a good sound turf. The water should find its way into the drain from the sides, and not from the top."

"Stones broken to the size above mentioned are expensive in this country, and in many places they cannot be procured; in England, it is now found that tiles, made of clay and burned, are cheapest. These have been made of various shapes.

"The first used was the horse-shoe tile. This was so named from its shape; it had a sole made as a separate piece to place under it, and form a smooth surface for the water to run over.

"Within a few years this tile has been almost entirely superseded by the pipe tiles (which are merely earthenware pipes, of one inch bore or larger, and made in short lengths). These tiles have a great advantage over the horse-shoe shape, in that they are smaller, and are all in one piece; this makes them cheaper in the first cost, and also more economical in the transportation.

"All these varieties are laid in the bottom of the ditch, it having been previously made quite smooth and straight. They are simply placed end to end, then wedged a little with small stones, if necessary, and the earth packed hard over them. Water will always find its way through the joints. Such pipes, laid at a depth of from 2½ to 3 feet, and at proper distances between the drains, will, in time, dry the stiffest clays. Many farmers have thought that water would not find its way in, but experience will soon show

them, that they *cannot keep it out.* The portion of earth next the drain first dries; as it shrinks on drying, little cracks begin to radiate in every direction, and to spread until at last they have penetrated through the whole mass of soil that is within the influence of the drain, making it all, after a season or two, light, mellow, and wholesome for plants."

"They form a connected tube, through which water runs with great freedom, even if the fall is very slight. When carefully laid, they will discharge water, where the fall is not more than two or three inches per mile. If buried at a good depth, they can scarcely be broken; and if well baked, are not liable to moulder away. There seems no reason why well made drains of this kind should not last for a century. The pipe tiles are used of from 1 to 1½ inches diameter of bore for the smaller drains, and for the larger, up as high as 4 or 5 inches. They are all made in pieces of from 12 to 14 inches in length. An inch pipe will discharge an immense quantity of water, and is quite sufficient for most situations. These small drains should not ordinarily be carried more than 400 to 500 feet before they pass into a large one, running across their ends. Where a very great quantity of water is to be discharged, two large-sized horse-shoe tiles are often employed, one inverted against the other.

"Third, as to the direction in which the drain should run. The old fashion was to carry them around the slopes, so as to *cut off* the springs; but it is now found most efficacious to run them *straight down*, at regular distances apart, according to the abundance of water and the nature of the soil. From 20 to 50 feet between them, would probably be the limits for most cases. It is sometimes necessary to make a little cross-drain, to carry away the water from some strong spring. In all ordinary cases, the drains running straight down, and discharging into a main cross-drain at the foot, are amply sufficient."

"Tile machines are now introduced into this country, and tiles will soon come into extensive use. Their easy portability, their permanency when laid down, and the perfection

of their work, will recommend them for general adoption. It is also to be noticed, that it takes less time to lay them than stones, and that the ditch required for their reception is smaller and narrower. The bottom of it need only be wide enough to receive the tiles. The upper part of the earth is taken out with a common spade, and the lower part with one made quite narrow for the purpose, being only about four inches wide at the point. The bottom is finished clean and smooth, with a peculiar hoe or scoop. This is necessary, because the tiles must be laid on an even smooth foundation."

With regard to these mechanical modes of improving the soil, it may be stated with truth—

1. That except in some cases of naturally deep and well-drained soils, no soil has a fair chance of showing its capabilities without deep ploughing and draining.

2. That many partially exhausted soils may have their fertility restored by these processes.

3. That the deepening and loosening of the soil occasion no waste of manures, but the reverse.

4. That when judiciously conducted these improvements have proved themselves to be among the cheapest and most profitable that can be attempted.

CHAPTER XII.

IMPROVEMENT OF THE SOIL BY MANURES.

§ 1. *General Nature of Manures.*

Any substance added to the soil by the farmer for its improvement, or the sustaining of its fertility, may be considered as a manure. Such substances may be regarded from different points of view, according to their origin, nature, and uses.

Some manures are supplied by animal and vegetable substances, others by mineral substances; hence the distinction arises of *organic manures*, and *inorganic manures*.

Some are *produced on the farm*, from the crops it has yielded, and their application only restores what has been taken away; others are obtained *from abroad*, and so are actual additions to the soil.

Some act *directly* as food to plants, others also *indirectly*, by making other substances useful; and they may do this either by rendering insoluble matters soluble, or on the other hand, by fixing in the soil substances which might escape from it in a volatile state. For instance, gypsum may act directly by affording sulphuric acid, and indirectly by fixing ammonia.

Some are *general* manures, that is, they are more or less beneficial on all soils, and to all plants. Of this kind are the ordinary stable manures and composts. Others are *special*, with reference to particular soils needing them, or with reference to particular kinds of plants. Of this kind are such substances as nitrate of soda, gypsum, and superphosphate of lime.

Some afford nourishment principally to the *organic* part of plants; and of this kind the most important are those

which can supply ammonia and carbonic acid. Others afford the materials of the *inorganic* part of the plant; and of this kind are the various mineral manures, ashes, and some kinds of guano.

In considering any manure, it is necessary to have regard to all these various uses, if we would wish to estimate its value or understand its action. For the present purpose we shall class manures as organic and inorganic, and shall notice under each its relations to various soils and plants.

§ 2. *Organic Manures.*

Under this head, I group all those fertilizing substances which have formed parts of animals or plants, and are restored to the soil, whence, or by the aid of which, they were obtained; though some of them cannot, in strict chemical language, be termed organic.

Stable Manures.—One of the ablest of British American agriculturists has said, "More than one-half of the manure made in the provinces is absolutely wasted from ignorance and inattention; and the other half is much more unproductive than it would have been under more skilful direction. We have almost no pits dug upon a regular plan, for the collection and preservation of the dung which, from time to time, is wheeled out of the barn. Sometimes it is spread out on the green sward; sometimes cast carelessly in a court, or adjoining yard; but seldom is an excavation made, purposely for retaining the juices which run from it. These are suffered either to stream along the surface, or sink into the earth; and in either case, their utility is sacrificed to inattention or ignorance. This is no more, however, than half the evil. The exhalations which arise from the ardent influence of the summer's sun, or from the natural activity of fermentation, are permitted to escape freely, and to carry with them all the strength and substance of the putrescible matter."*

* Young's "Letters of Agricola," Halifax, 1822.

There is, no doubt, much more attention given to this important subject now; but still, the waste of barn-yard manure, both solid and liquid, is a great evil, and a fruitful cause of agricultural poverty, and failures of crops. About two years ago, I had referred to this subject in a public lecture, and happened, immediately afterward, to drive ten or twelve miles into the country, with an intelligent friend, who doubted the extent of the loss. We were driving through an old agricultural district, and, by way of settling the question, determined to observe the capability of each barn-yard that we passed, for the preservation of manure. It was in early spring, and we found scarcely one barn that had not its large manure heap perfectly exposed to the weather, and with a dark stream oozing from its base into the road-side ditch, or down the nearest slope; while there was evidently no contrivance whatever, for saving the liquid manure of cattle. Here was direct evidence, that a large proportion, probably not less than one third, of the soluble part of the solid manure, and the whole of the liquid manure, which all agricultural chemists think to be at least equal in value to the solid part, was being lost. In other words, each farmer was deliberately losing between one-half and two-thirds of the means of raising crops, contained in his own barn-yard. What would we think of a tradesman or manufacturer, who should carelessly suffer one half of his stock of raw material to go to waste; and the case of such farmers is precisely similar. The results of chemical analysis will enable us to form more precise ideas of the nature and amount of this waste.

Composition of Solid Stable Manure (Richardson).

Carbon	37.40
Hydrogen	5.27
Oxygen	25.52
Nitrogen	1.76
Ashes	30.05
	100.00

Composition of the Ashes of Stable Manure (Richardson).

Potash	3.22	Soluble in water.
Soda	2.70	
Lime.	0.34	
Magnesia	0.26	
Sulphuric Acid	3.27	
Chlorine	3.15	
Silica	0.04	
Phosphate of Lime	7.11	Soluble in Hydrochloric Acid.
" of Magnesia	2.26	
" of Oxide of Iron	4.68	
Carbonate of Lime	9.34	
" of Magnesia	1.63	
Silica	27.01	
Sand, &c	34.96	
	100.00	

Composition of Liquid Stable Manure (Boussaingault).

	Horse.	Cow.
Urea	31.00	18.48
Hippurate of Potash	4.74	16.51
Lactate of Potash	20.09	17.16
Carbonate of Magnesia	4.16	4.74
" of Lime	10.82	0.55
Sulphate of Potash	1.18	3.60
Chloride of Sodium	0.74	1.52
Silica	1.01	— —
Water, &c	910.76	921.32
	1000.00	1000.00

Urea, the principal organic ingredient of Urine, consists of—

Carbon	20.0
Hydrogen	6.6
Oxygen	46.7
Nitrogen	26.7
	100.0

Urea is very rich in nitrogen. In decomposing, it changes into carbonate of ammonia, which rapidly es-

capes, unless prevented by some absorbent material, as charcoal, or by the chemical action of sulphuric acid or gypsum.

In the above table, we see that the liquid manure contains large quantities of potash and soda; and that a large portion of it is urea, a substance very rich in nitrogen, and, in fact, quite similar to the richest ingredients of guano. Johnston estimates the value of 1000 gallons of the urine of the cow, to be equal to that of a hundred weight of guano. The farmers of Flanders,—who save all this manure in tanks,—consider the annual value of the urine of a cow to be $10.

In the solid manure, we perceive that there is little nitrogen. This element, so valuable for producing the richer nutritious parts of grain and root crops, is principally found in the liquid manure. The little that is present, however, in the solid manure, is soon lost in the form of ammoniacal vapours, if the dung be allowed to ferment uncovered. The other organic matters are less easily destroyed, unless the dung be allowed to become "fire-fanged," in which case the greater part of it is lost. In the ashes, or inorganic part, we find all the substances already referred to as constituents of fertile soils; and many of the most valuable of them are, as the manure decomposes, washed away, and, along with a variety of organic matters, appear in the dark-colored water which flows from exposed dung-hills. It is not too much to say, that the loss of the volatile and soluble parts of manures, on ordinary upland soils, cannot be repaid by any amount of outlay in the purchase of other manures, that our farmers can afford; and we can plainly perceive, that the prevailing neglect in this one particular, is sufficient to account for the deterioration of once fertile farms. How, then, is this waste to be prevented? In answer to this, I shall merely indicate the principles on which the means adopted for saving manures should be founded, with a few general hints on the best modes of carrying them into effect.

1. The solid manure should be covered with a shed or roof, sufficient to protect it from rain and snow. Its own natural moisture is sufficient to promote, during winter, a

slow and beneficial fermentation. Snow only prevents this from going on; rain washes away the substance of the fermented manure.

2. The ground on which the manure heap rests, should be hollowed, and made tight below with clay or planks; and in autumn, a thick layer of bog mud, or loam, should be placed on it, to absorb the drainings of the manure.

3. When the manure is drawn out to the field, it should be covered as soon as possible, either in the soil, or, if it must stand for a time, with a thick coating of peat or loam,—a pile of which should be prepared in autumn for this purpose. All unnecessary exposure should be avoided.

4. Where gypsum can be procured cheaply, it should be strewed about the stables, and on the manure heap, for the purpose of converting volatile ammoniacal vapours into *fixed* sulphate of ammonia. This will also render the air of the stables more pure and wholesome.

5. It must be borne in mind, that the richest manures are the most easily injured. For example, many farmers think horse manure to be of little value. The reason is, that when exposed it rapidly enters into a violent fermentation and decay, and its more valuable parts are lost. Such manures require more care than others, in protection and covering, so as to moderate the chemical changes to which they are so liable, and to save the volatile and soluble products which result from them.

6. The liquid manure should be collected, either in the pit or hollow intended for the other manure, or in a separate pit prepared for the purpose. The latter is the better method. If a tight floor can be made in the stable, it should be sloped from the heads of the cattle, and a channel made, along which the urine can flow into the pit. If the floor is open, the pit should be directly beneath it, or the ground below should be sloped to conduct the liquid into the pit. In whatever way arranged, the pit should be tight in the bottom and sides, and should be filled with soil, or peaty swamp mud, to absorb the liquid. Gypsum may also be added with great benefit; and the urine pit may very well form a receptacle for door-cleanings, litter which may accumulate about the barn, and every other

kind of vegetable or animal refuse. These additional matters may occasionally be protected, by adding a new layer of peat or soil to the top. The pit for liquid manure should be roofed over. A method much followed in Britain and the continent of Europe, is to collect the urine in a tank, and add sulphuric acid to prevent waste of ammonia. When used, the liquid is diluted with water, and distributed to the crop by a watering cart. This is too expensive for most of our farmers; but when it can be followed, it will be found to give an astonishing stimulus to the crops, especially in the dry weather of spring. Gypsum may be put into the tank, instead of sulphuric acid.

In a prize essay on manures, by Prof. Way, published by the Royal Agricultural Society of England, the following analysis is given of the drainings of a dung-heap, composed of the mixed manure of horses, cattle, and sheep, and in a well rotted condition. The fluid examined was that washed out with rain water, and was of a deep brown color. It contained in each imperial gallon 764.64 grains of solid matter, of which 395.66 were volatile and combustible, and 368.98 incombustible or ashes. Its composition was as follows:—

I. Combustible Part.		
Ammonia, in a soluble state..........	36.25	
do in fixed salts..............	3.11	
Ulmic and humic acids......	125.50	
Carbonic acid.....................	88.20	
Other organic matters (containing 3.59 of Nitrogen..................	142.60	
	——	395.66
II. Incombustible Part.		
Soluble silica......................	1.50	
Phosphate of lime, with a little phosphate of iron..................	15.81	
Carbonate of lime..................	34.91	
Carbonate of magnesia..............	25.66	
Sulphate of lime....................	4.36	
Chloride of sodium..................	45.70	
Chloride of potassium..............	70.50	
Carbonate of potash...............	170.54	
	——	368.98
Total per gallon................		764.64

It will be observed that the combustible part contains a large amount of ammoniacal matter, and the rest is principally the richest humus or vegetable mould; while the incombustible part contains all the ingredients in the ashes of cultivated plants, and these in a soluble state, ready to be absorbed by the soil and taken up by the roots. This table, in short, affords the most conclusive evidence of the immense loss sustained by the farmer who allows his stable manures to be weathered, and their soluble part washed away by the rains. No economy in other respects, and scarcely even the most costly additions of artificial manures, can compensate this waste.

This subject is, in all its details, deserving of the careful study of every practical farmer.

§ 3. *Organic Manures* (continued).

The remaining organic manures may be arranged under the following heads:

1. Those which, like peat, bog mud, leaves, spent bark, saw-dust, straw, &c., consist principally or exclusively of woody fibre. These substances decay but slowly in the soil, and do not yield large quantities of the more rare and valuable of the substances required by cultivated plants. They are useful, however, in two points of view. They renew the supply of vegetable matter in the soil, and thereby ameliorate its texture; and they afford, by their decay, substances useful in enabling plants to build up the tissues of their stems and leaves. They are also admirable absorbents for the richer parts of putrescent manures; and by mixture with these substances, they are themselves more rapidly decomposed. Their use, therefore, is, as already indicated, to fill the urine pit, to form the basis of the dung-hill and the cover of composts, and to serve as litter in the stable and cattle yard. They may also be used in top-dressing grass,—which they not only nourish, but protect from the frosts of winter.

2. A second class consists of the rapidly decomposing remains of animals and plants,—as dead animals, blood,

night-soil, fish-offal, parings of hides, green succulent weeds, sea weeds, &c. The animal manures of this class, are of great value, being almost entirely composed of the materials which are most wanted for the production of the most nutritious parts of vegetables. The vegetable manures of this class, though less valuable, afford, in addition to their woody fibre, much alkaline matter and some nitrogen; and some of them contain animal substances which add greatly to their value. Such manures should not be left exposed, nor should they, except in case of necessity, be applied in a fresh state to the land; as in their raw state, a slight excess of them often exerts a poisonous influence, and much of their richness is also apt to be wasted. They should be mixed with earth or peat, in the proportion, in the case of the richer kinds, of three to one, and well covered with a coating of earth. The whole mass will thus become a rich and valuable manure. In many places, there is sufficient fish offal, if treated in this way, to fertilize large tracts of barren land; whereas it is now totally wasted, or spread on grass land, to taint the air with odours which, if retained under ground, would furnish the elements of life and vigour to the crops. The same remark applies to dead animals, and all the putrescent refuse which is apt to accumulate about yards and outhouses. Exposed on the surface, these things are pestilential nuisances; buried in the compost heap, they are the materials of subsistence and wealth.

As *Sea weed* is a very important manure, and is extensively applied in many parts of the sea coast, a few additional remarks may be made, respecting its composition and uses. The ashes of sea weed have been found to contain:

Soda and Potash...............	15 to 40 per cent.
Lime	3 " 21 "
Magnesia.....................	7 " 15 "
Common Salt..................	3 " 35 "
Phosphate of Lime	3 " 10 "
Sulphuric Acid................	14 " 31 "
Silica.........................	1 " 11 "

These are all important substances, and, in addition to the nitrogen contained in the organic part of the weed, must exercise an important influence. Sea weed, however, is but a temporary manure, as it decays very rapidly; and it is extremely unwise to place the whole dependence on it, to the exclusion of other manures, especially of the stable manure. The farmer should save his stable manure, and consider the sea weed an additional, or supplementary aid. In this way, there will be no danger of his having to complain that, notwithstanding constant applications of sea manure, his land is becoming poor. He must also remember, that sea weed does not contain all the materials of land plants, in due proportion; and that, therefore, it cannot supersede the necessity of other fertilizers. With respect to composting sea weeds, some good farmers on the sea coast compost carefully all the weed obtained in autumn, and apply, in the recent state, that procured in spring. It has also been successfully applied as an autumn dressing to grass. This is certainly better than the practice, which I have observed in some places, of top-dressing grass with the stable manure, and applying nothing in the drills with green crops but sea weed.

Land weeds form a somewhat useful kind of manure, as they are often rich in alkalies, and other constituents of crops. Rank road-side weeds are especially valuable; and their removal prevents the dissemination of their seed, and improves the appearance of the country. The ploughing in of green vegetables—as buckwheat, clover, or turnip tops,—may also be considered as the application to the soil of a somewhat rich vegetable manure of this class.

3. A third class is formed of those manures of animal and vegetable origin which, though highly fertilizing, are not liable to rapid decay; and are, therefore, permanent in their effects, and may be kept for application in a dry state. Such are bones, hair, hoofs, hen manure, guano, wood ashes, and soot.

Bones are of great value, as they afford that rare and important substance, phosphate of lime, along with a rich animal matter; ground bones, and "bone dust," are now

an important article of traffic as manure, and are of great value,—as five bushels are considered to be sufficient manure for an acre of turnips, especially if mixed with a little wood ashes. Every farmer should collect and apply bones. They are very valuable, even after being burned or boiled with potash for soap, because they still contain their phosphate of lime, though deprived of their animal matter. Where means for grinding bones cannot be obtained, they may be broken into small pieces by the hammer; they may then be mixed with an equal quantity of earth or ashes, moistened, and left to heat before being put into the drills. For practical illustrations of the value of bones, I may refer to Jackson's Agriculture. Among other instances, he mentions, that a dressing of 600 bushels on 24 acres of poor pasture, had so improved the grass, as to double the yield of butter; and this effect endured for many years. In this case the pasture had been laid down for ten years, and, no doubt, much of its natural phosphate of lime had been exhausted, to form a constituent in the milk and bones of the cattle that had fed on it. In another case, he mentions a ten-fold yield of turnips, and a great improvement in succeeding grain crops, as resulting from its application.

Hair and *Hoofs* are rich manures, though they decay slowly. Such substances, from tanneries, &c., should be saved, and applied to the land. At the rate of twenty or thirty bushels per acre, they produce marked effects.

Guano is a manure produced by the slow decay of the droppings of sea birds, in dry climates, and is chiefly obtained from islands on the coast of Peru. It is very rich in nitrogen and phosphates, and may hence be regarded as the most concentrated form in which the most rare and expensive parts of the food of plants can be supplied. It contains, in the solid form, all the substances which are present in liquid manure in a state of solution. From two to four cwt. of guano per acre on most soils will raise a good crop of turnips, and a succeeding grain crop; but as guano does not contain much of the ruder and more common organic matters useful in the soil, it is best to use

one or two cwt. of guano, with half the usual quantity of other manure. To render the guano more easily applied, it should be mixed with sand or dry soil before sowing it.

Guano is one of the most valuable of manures, and is especially applicable to soils worn out by the culture of grain crops. Peruvian guano contains from fifty-six to sixty-six per cent. of ammoniacal salts and organic matter, and from 16 to 23 per cent. of phosphates. Very excellent artificial guano is now made in Newfoundland and in Maine from fish refuse, by boiling, pressing, and drying, and then coarsely grinding or crushing. When pure and genuine, these artificial guanos are among the most rich of portable manures.

Wood ashes may be applied with any crop; but not in very large quantity, as they not only act powerfully as a manure, but exert a caustic or decomposing influence on organic manures, and on the roots of plants. Fifty bushels per acre, is the largest quantity that can be safely applied to heavy soils, rich in vegetable matter. Lighter soils should have a much smaller quantity; and on light soils even a few bushels will produce marked benefits. *Kelp*—or the ashes of sea weed—and peat ashes, are similar in their effects to wood ashes, but less powerful.

The great value of wood ashes may be estimated from the remarkable effects produced by them in new land, where the ashes of forests, the growth of centuries, are at once applied to the surface. The substances which they afford, may be learned from the following analysis of the ashes of beech wood:

Potash	15.83	per cent.
Soda	9.79	"
Common Salt	0.23	"
Lime	62.37	"
Gypsum	2.31	"
Magnesia	11.29	"
Oxide of Iron	0.79	"
Phosphoric Acid	3.07	"
Silica	1.32	"

These are the principal subtances on which new land depends for its fertility; and the loss of which, either by

wasteful cultivation or by repeated burnings followed by rain, causes its exhaustion. These ashes produce the best effects when a considerable proportion of the vegetable matter of the soil remains unconsumed; both because this vegetable matter serves to retain the ashes, and because it prevents their caustic effects from being too strongly felt. On the other hand, when the vegetable matter is entirely consumed, the ashes are rapidly wasted, and the crops suffer from deficiency of organic manure. Leached ashes, having lost their potash and soda, are of less value than recent ashes, but are still of great utility.

Peat ashes, though less valuable than those of wood, have been extensively used as manure, especially in Holland, and in applying peaty matter as manure, the value of its inorganic part should be taken into account. Hunt gives the following analysis of the ashes of peat from St. Dominique, C. E.:

"A watery solution of the ash contained chlorine and sulphuric acid combined with potash and soda, and a large amount of sulphate of lime. The whole of the alkaline salts were dissolved by the water. The ash was strongly alkaline in its reactions, and contained, as might be expected, the magnesia and some of the lime in a free state." 100 parts of it gave me:

Lime	47.040
Magnesia	3.150
Peroxyd of Iron	4.680
Alumina	2.440
Oxyd of Manganese	.040
Potash	.330
Soda	.254
Chlorine	.247
Sulphuric Acid	9.175
Phosphoric Acid	.932
Carbonic Acid	23.060
Silica	4.920
Sand (mechanically present)	4.040

These ingredients combined in the usual manner, will give the following compounds for 100 parts:

Carbonate of Lime	52.410
Lime } in part as silicates	10.431
Magnesia } in part as silicates	3.150
Peroxyd of Iron	4.680
Alumina	2.440
Oxyd of Manganese	.040
Phosphate of Lime	2.019
Sulphate of Lime (gypsum)	15.085
Sulphate of Potash	.605
Sulphate of Soda	.076
Chlorid of Sodium	.412
Silica	4.920
Sand	4.040
	100.308

Such a substance must act powerfully on any soil in want of sulphates, phosphates, lime, or silica, and it is probable that the ashes of peat from most of our bogs would be found to possess similar properties.

Soot contains ammonia, and sulphates, carbonates, muriates and phosphates of lime, potash, soda, magnesia, &c. It is, therefore, a very powerful manure, and, like guano, need be applied but in small quantity.

To this class of manures, I may add the offal of codfish, which may be obtained in large quantity in some of the fishing districts. If dried, and packed in old barrels or crates, it might be preserved, and conveyed into the interior districts. As it consists entirely of phosphate of lime and rich animal matter, it is nearly as valuable as guano, and would be well worth 5s. or 6s. per cwt. It should be cut up, or crushed, and mixed with soil to ferment before being applied. It should be used in drills with potatoes or turnips.

It may also be of service to add here, that night-soil, urine, and other offensive animal substances, may be converted into a manure of great power, and quite inoffensive, by mixing them with powdered charcoal, or charcoal and gypsum. They may then be sown like guano, and will produce similar effects. Artificial manures, called *poudrettes*, are often prepared in this way. Farmers would find it profitable, to have constantly at hand a quantity of charcoal and powdered gypsum, for such purposes.

§ 4. *Mineral or Inorganic Manures.*

After what has been already said, it is scarcely necessary to mention here that manures of this kind may be as truly the food of plants as substances that have already actually formed parts of vegetable substances. Any of the substances mentioned above as necessary ingredients in fertile soils, or in the ashes of crops, may produce valuable effects, if they can be procured from the rocks of the earth, or any other source, and applied to the land. The beneficial influence of these substances may be summed up under the following heads :—

1. They may supply original chemical or mechanical wants in the soil. They may furnish substances required by some or all crops, and previously deficient; and thus not only directly promote their growth but enable them to avail themselves of other materials which, though abundant, they could not use, from want of that which was deficient. For instance, if clover contains in its ashes 28 per cent. of lime, and if the soil contains so little that, in the course of the season, the plants can get only half the quantity they require, they will take just so much less of everything else, and produce little more than half a crop. Hence the addition of lime to such a soil will enable clover to take a great deal more of other kinds of food, and the effect on the crop will be very marked. On the other hand, if the soil contain a sufficiency of lime, its addition as a manure may produce no appreciable effect. We learn from this, the nature, in part at least, of what is called the stimulating and exhausting effect of mineral manures, and also the reason of their frequent failure. A farmer who finds by experience that some mineral ingredient, as lime, gypsum, &c., produces marked benefit, continues to apply it, and neglects other manures, until at last it produces no effect, and he finds that his land is completely run out. He now says that, after all, his supposed fertilizer was only a "stimulant," and condemns it; whereas the error is in his own ignorance of the fact that, though necessary to fertility, it only rendered more necessary a sufficient quan-

tity of the other kinds of food required. It is just as if a farmer were to find the appetite and flesh of his cattle falling off, and were to add some salt to their food; and finding this to remedy the evil, were to withhold all other nourishment and attempt to feed them on salt alone. It is easy to fall into an error of the opposite kind. A farmer, anxious to improve, learns that great benefits have resulted from some mineral manure. He at once applies it on a large scale, and is surprised to find that it does no good whatever. The reason probably is, that his land has already enough of it, while that to which it has been successfully applied had not. He should have ascertained by experiment on a small scale, or by an analysis made by a competent person, the actual state of his land in reference to this particular substance; and then he might have proceeded with certainty. These errors, arising from imperfect knowledge, work incalculable mischief to the cause of agricultural improvement. The true course with respect to mineral manures, is to test the land as to its wants; and then to supply what it needs, without neglecting other ordinary manures.

2. Mineral manures may produce chemical changes in the soil, which may preserve or render useful other substances previously present, or may decompose poisonous ingredients. I have already had occasion to notice the effect of gypsum in saving ammonia, and that of lime in decomposing sulphate of iron, and neutralizing vegetable acids. Lime also exerts a powerful influence in decomposing inert vegetable matter, and even small stones and gravel which may contain matter useful to the soil. This is what we may call, if such a term can be properly used, the true *stimulating* effect of mineral manures.

After these general remarks, it will not be necessary to dwell at any great length on the separate mineral manures. I shall therefore briefly indicate their uses, sources, and the modes in which they may be best applied.

Lime is an important ingredient in the ashes of most plants. It also renders the soil lighter, and promotes the decay of vegetable matter. In consequence of this last

property, it can be applied in the largest quantities to heavy lands, rich in vegetable matter; on light and poor lands it should be used with caution. I have already pointed out in treating of soils, many kinds of land to which it may be advantageously applied; and where this is doubtful, an opinion of its necessity may be formed by observing whether the crops already referred to as containing much lime, such as clover and some of the green crops, thrive on the land in question; and by trying experiments on a small scale. When competent chemical aid can be obtained, an analysis of the soil may be resorted to in cases of difficulty.

Lime exists most abundantly in the state of carbonate, either in the form of limestone or in the substances called marls, and which consist of mixtures of carbonate of lime with sand and various earthy matters. Lime, in both of these states, is abundant in most parts of this country; though it may be observed, that those tracts whose soils are most deficient in lime, are precisely those in which beds of limestone and marl are most rare.

Marl is found in large beds, especially in the gypsiferous districts of New Brunswick and Nova Scotia. These large marl beds are usually of grey or brown colors, and often contain small irregular veins of gypsum. The decaying surface of many beds of limestone also affords a substance which may be classed with the marls. In some low grounds which have formerly been ponds or lakes, there are beds of clay mixed with fresh-water shells; and in creeks and harbors, there are mussel and oyster beds which afford a similar substance, containing also much valuable animal matter; these are known as shell marls. They exist in very many parts of Canada, numerous localities being noticed in the Reports of the Geological Survey. On some parts of the coast also, large quantities of sea-shells, mixed with sand, may be collected on the beach, and may be called shell-marl, as they are quite analogous in composition and effects. All these substances may be applied in large quantity with benefit to most soils; more especially as in this mild state the lime exer-

cises no destructive influence on the organic matter of the soil. The earthy marls may be used for mixing with composts, or laid on as a top-dressing. The shell marls which contain much animal matter, should be covered and composted with earth, and applied with root or grain crops. Marls may be distinguished from common clays and sands by a very simple test. Put a little of the substance into a wine glass or tumbler, and add a little water, sufficient to make it into a thin paste. Then pour in a few drops of muriatic acid, and observe if any effervescence or boiling up occurs. If a good marl, it will boil up with considerable force; if a poor one, with less force; and if not a marl at all, there will be no effervescence or scarcely any. Limestone may be distinguished from other rocks in the same way.

Limestone ordinarily requires to be burned in order to be rendered fit for application to land. Burning deprives it of its carbonic acid, and brings it into the state of quick or caustic lime, or after it is slaked with water, into that of hydrate of lime, or lime combined with water. In these forms, it is most suitable for mixing with crude vegetable matters, as peat, which it is desirable speedily to decompose, and also for application to some bogs; but in these forms its application in large quantity to very light soils is most dangerous. It remains, however, but a short time in the state of caustic lime, for whether in the soil or on the surface, it gradually absorbs carbonic acid from the air and from the organic matters with which it comes into contact, and passes back into the state of carbonate, the same state in which it was before being burned; so that ultimately the principal result of the burning is that of reducing the lime to fine powder, which can be uniformly diffused throughout the soil. This change does not, however, fully take place for a very long time. It is principally this strong affinity for carbonic acid, which causes lime to hasten the decomposition of organic matters, by creating a powerful demand for the carbonic acid which is one of the principal products of their decay; and as this carbonic acid is a useful part of the food of plants, in poor soils an excess

of caustic lime not only wastes the organic matter, but takes away the little vegetable food which it is producing. In like manner, caustic lime is altogether unsuitable for mixing with rich animal manures, as the rapid decay which it induces sets free and wastes all the ammonia which they contain. This is well shown by mixing a little quick lime with guano. The intense odour of ammonia given off, indicates at once the destructive action of the lime, and the large quantity of ammonia in the manure. If a rod dipped in muriatic acid be held over the mixture, the ammonia becomes visible as a white cloud of muriate of ammonia.*

As a decomposing agent, then, quick lime is most rapid and efficient, but mild lime acts in the same way, though more slowly. To the action of both kinds, however, the presence of air is necessary. The oxygen of the air is required in the decay of all kinds of organic matter, and since lime acts in promoting decay, its influence will in a great measure depend on the greater or less readiness with which air can penetrate to the vegetable matter of the soil. For this reason, when lime is mixed with organic matter in close vessels or in very stiff impermeable clays, it tends to harden and preserve, rather than to decompose it; in such soils therefore, draining and loosening the ground are necessary in order that lime may exert its proper influence

The decomposing power of lime, explains its beneficial influence on peat-bogs, and other soils surcharged with moisture and undecayed woody matter. In such places the vegetable matter long soaked in stagnant water, produces in the slow changes which it undergoes, the humic, ulmic and other organic acids, which communicate what is very properly named sourness to the soil, and render it fit only for the growth of coarse grasses, ferns, moss, and similar plants. But when lime is applied, it enters into combination with these acids, and at the same time causes the inert woody matter to decay and fill the soil with products valuable as food for plants. It is to this cause that

* The same test indicates the escape of ammonia from rich manures, when decaying too rapidly.

we must also in great part ascribe the beneficial change which lime effects in pasture lands overgrown with coarse grasses, or more useless herbage, causing this rank vegetation to give place to tender grasses and clover. In all these cases the lime is merely the means of bringing into a useful form a quantity of matter previously existing in the soil in an inactive or positively injurious state. In the case of swampy land, however, we must not forget that lime will prove only apartial and temporary remedy, unless it be assisted by draining.

The facts already stated will enable us to understand the utility of composting peat, black swamp mud, and similar substances, with lime. By the decomposition which they are thus caused to undergo, they are converted into valuable manures.

Since the benefit of lime arises in great part from its power of bringing into use the stores of food already present in the soil, it is plain that its effects must be greatest in soils which contain abundance of vegetable matter, and also that its tendency is to *exhaust* this matter more rapidly than if lime were not used. Heavy liming, therefore, when not accompanied with other manures, must, at each successive application, produce less effect, and end in causing comparative barrenness. From observing this injurious effect of the misapplication of lime has arisen the English proverb that, "Lime makes rich fathers, but poor sons." The Germans have a better proverb, to the effect that heavy liming and heavy manuring must go together.

These considerations also show how lime may "burn up" and impoverish some light soils, by wasting with unnecessary rapidity their already small stock of vegetable mould. When applied to such soils, lime should be either in the form of clay marl, or of composts made of peat, sods, ditch cleanings or similar matters, which will furnish it with materials to act upon, without exhausting the soil.

Lime also exerts an important *influence on the inorganic materials of soils*. It has been already mentioned that the soluble salts of iron present in some boggy lands, and injurious to vegetation, are decomposed by lime, owing to

its superior affinity for the acids which they contain. Another change of the mineral matter of the soil, effected by lime, depends on its affinity for silica, which is sufficiently powerful to enable it gradually to decompose fragments of granite, trap, and other rocks, consisting of silicates, combining with their silica, and setting free their potash, soda, &c., in forms very useful to crops. Beside these, there can be little doubt that lime aids in effecting many other changes among the mineral ingredients of soils, tending in many cases to make their constituent parts more available for the nourishment of vegetation.

Duration of the effects of Lime.—When lime, in the quick state, is placed in the soil, it acts energetically, from the moment of its application until it is reduced to a state of partial mildness, when its influence is exerted more slowly. This slower action, however, continues with unabated, or even increasing vigor, for two or three years; and although it may then diminish, the influence of a heavy liming may be felt even thirty years after its application. The decrease of the influence of lime may be accounted for in different ways. It is usually applied only to the soil near the surface, and has a tendency to sink downwards into the sub-soil. In light soils, this may be caused by the fineness of its particles, which causes them to be washed down between the coarser grains of the soil. In rich and close soils, however, it is very probably due to the earth-worms, those industrious agriculturists, which are constantly employed in carrying to the surface the finer parts of the soil, on which they feed, a process which must result in the burying of every substance which they are not inclined to devour. Lime is also dissolved by water impregnated with carbonic acid, and is rendered soluble by combining with various acids present in the soil, and in these states much of it is absorbed by the roots of crops, and much washed away from the ground by rains. Another mode in which the influence of lime may gradually become insensible, is by its combining with silica, and forming an insoluble compound, possessing none of the active properties of lime.

Quantity of Lime which should be applied.—When land is originally destitute of lime, a large quantity may be mixed with the soil, with beneficial results. This will be evident when we consider that in order to give one per cent. of lime to a soil six inches deep, we must apply above three hundred bushels of lime to an acre. If, therefore, the lime be well mixed with the soil, a large quantity may be used without producing any very great change. The quantity of lime which should be applied, depends however, in a very great degree, on the nature of the soil. Clay ground and swampy land are often benefitted by very large doses; as much as seven hundred bushels on the acre have been added to land of this description, without producing any bad effects. Light and sandy soils, on the other hand, may be injured by a dose which would be much too small for clay land. To these circumstances, therefore, attention must be paid, as well as to the proportion of lime naturally present.

Since lime gradually disappears from the soil, it is necessary that the supply should be renewed at intervals; and it is plain that a more uniform effect will be secured by adding small quantities frequently, than by using large doses at long intervals. The practice of farmers has, however, varied very much in this respect, according to their various circumstances. In some parts of Scotland, forty-six bushels of quick lime per acre, are applied every five years; in others, two hundred to three hundred bushels are used once in nineteen or twenty years. In Flanders, ten to twelve bushels are applied once in three years, or forty to fifty bushels once in twelve years. In many parts of England, lime is applied once in every rotation of three or four years. The different length of the intervals in these cases, does not appear to be of very great importance, and may be varied by every farmer to suit his own convenience. Small applications, at short intervals are, however, evidently safer and more efficacious than large doses seldom repeated.

Enough has now been stated to show the uses of lime and their reasons, and to prevent us from being deceived

by the hasty assertions, respecting its utility and inutility, frequently made by persons whose views on the subject are only partial. The results of an enlightened view of what is known with respect to this valuable manure, may be summed up as follows:—

1st. Lime has *ultimately* the same effects whether it be applied in the quick, air-slaked, or mild state; it should be well mixed with the soil, but kept as near the surface as possible; and it should be renewed at intervals of a few years.

2dly. The mechanical effects of lime in opening and loosening the soil, are always beneficial on heavy soils, except where these are very wet and undrained; and, on the other hand, they are sometimes injurious to very light and dry ground.

3dly. The chemical effects of lime, when properly applied, are—affording a necessary part of the food of crops; bringing into activity the inert vegetable matter of the soil, and decomposing some mineral compounds which are injurious to vegetation, and others whose constituents are of great utility when set free by its action. By these means it tends to discourage the growth of moss and many other useless plants in pastures and hay fields, and encourage that of valuable grasses and clover; to increase the quantity and improve the quality of grain and green crops; and to augment the benefit of vegetable manures.

4thly. When applied to land already abounding in lime, or very deficient in vegetable mould, it may produce no benefit; and applied in too large quantity, or when not accompanied with sufficient supplies of vegetable manures, it may be highly injurious by exhausting and impoverishing the soil.

5thly. Just as some cultivated plants cannot thrive without a good proportion of lime, there are some wild plants native to poor non-calcareous soils which are destroyed by liming. Hence, liming and sowing with grass are sometimes sufficient to replace the most useless plants with nutritious grasses.

Some varieties of limestone contain a large proportion of

magnesia, which, when added to the soil in large quantity, produces an injurious effect. These limestones are generally known as magnesian limestones or dolomites.

2. *Gypsum.*—The uses of this substance have already been often referred to. 1. Gypsum supplies sulphate of lime to crops, and, in general, is the cheapest form in which the sulphuric acid—shown by analysis to be present in the ashes of cultivated plants—may be obtained by the farmer. For instance, 1000 lbs. of dry clover and timothy hay, contain from 3½ to 4½ lbs. of sulphuric acid; or we may estimate the quantity of sulphate of lime, or gypsum, required by a moderate hay crop, at 20 to 30 lbs. per acre. When gypsum is naturally deficient in the soil, great results may be expected from its application, especially in the growth of those crops which contain large quantities of this substance. 2. Gypsum possesses great value, from its property of converting the carbonate of ammonia—one of the most volatile products of the decay of animal substances—into the sulphate of ammonia. This action has been already explained in treating of ammonia.

The influence of gypsum is thus very different from that of lime or marl. It does not tend either to waste or render available the vegetable matter of the soil; nor does it remove the sourness and coldness of heavy soils. On the contrary, it rather tends to give body to light soils. As already stated there is reason to believe that on many exhausted soils in the interior of Canada gypsum will be found to be of great value, the soils being deficient in sulphates. In the vicinity of the sea, experience has shown that gypsum is less useful than further inland; apparently because the sea spray carried by the wind supplies to the soil a small quantity of sulphate of soda, which serves instead of gypsum. Again: some soils, especially those in the vicinity of the gypsum beds, are already well supplied with this substance; and some soils in slaty districts, though deficient in gypsum, receive supplies of sulphuric acid from the sulphuret of iron contained in the slate. Coal ashes, peat ashes, and sea weeds, where applied, also furnish small quantities of gypsum. The second use of

gypsum, however, to which I have referred, is one that applies to all soils and situations. In the stable, the urine-pit, the dung-hill, and the compost heap, gypsum is always useful; and when scattered on the potato or turnip drills, or the hills of corn, it will always stand sentinel over the rich manures beneath, and preserve their ammonia in the soil. This is especially true in the case of light sandy soils. For such uses, every good farmer should always have at hand a supply of powdered gypsum.

The cheapest way of rendering gypsum fit for use, is to break it into pieces, and burn it after the manner of lime,—though it does not require so great heat as limestone. Burning only drives off its water, without producing any other chemical change. After burning, it may be easily crushed into powder; but must be kept dry, otherwise it will set into a solid mass. The fine rubbish of gypsum quarries, and also the marly beds in their vicinity, may often afford a very cheap supply of gypsum.

It may seem contrary to the above remarks in reference to gypsum, that in the United States, where plaster has been largely applied, it has been accused of running out, or impoverishing the land. This is well explained by Norton, on a principle already referred to: "In many cases, a few bushels per acre bring up land from poverty to a very good bearing condition; complaints are, however, made, that after a time it injures the land, in place of benefitting it. This, in almost all instances, results from using it alone, without applying other manures at the same time. The explanation is of the same general nature as that given under lime. The farmer has taken away a variety of substances, and has only added gypsum. If the land is entirely exhausted at last under such treatment, it is obviously not the fault of the gypsum. There are many large districts, where it produces no effect; but it may always be considered certain, that where gypsum or lime does no good, there is already, in one form or another, a supply of both naturally in the soil; or, as has been previously explained under lime, there is some physical or chemical defect, which prevents their action."

3. *Potash and Soda.*—The sources of these, in the ashes of plants, have been already referred to; and there are not many ways in which they can be directly obtained from the mineral kingdom. Sea salt contains soda in combination with chlorine; and it may be made more useful to plants by mixing it with quick lime. It will generally be found very useful to slake lime intended for land with sea water; and no better use can be made of refuse salt or brine, than to pour it upon quick-lime, or mix it with a lime compost. Granite contains a large proportion of potash; and though a granite compost may seem a strange thing, crushed granite has actually in England been mixed in heaps with quick lime, for the purpose of setting free its potash. This is the only recipe that I know, for meeting the wishes of a gentleman in one of our more rocky districts, who once said to me, "There would be some use in your agricultural chemistry, if you could dissolve these granite rocks for us." Farmers who can obtain the smaller dust and fragments of granite quarries and masons' sheds, where granite is worked, and who are not located on granitic soils, will find it pay to cart such material, and mix it with the lime they intend to apply to their land, covering the whole with a thick coating of clay, and letting it stand for a few months. The effect will be greater, if the granite be previously burned, like the lime. The softer varieties of trap rock, which also contain much alkaline matter, may be treated in the same way; or may be usefully applied to poor soils without any preparation.

4. *Phosphate of Lime.*—Small quantities of this highly valuable substance, are contained in most limestones, and conduce greatly to the benefits resulting from liming. Those varieties of lime which contain large numbers of impressions of shells and scales of fishes, are usually most valuable in this way. Some thin and impure limestones of little use for ordinary purposes, are rich in phosphates. This is especially the case with beds containing many of the fossil shells called *Lingulæ*, and with some beds of the coal districts containing scales of fishes. At North Elmsley and South Burgess in Upper Canada, there are beds

of crystalline phosphate of lime, which are quarried for exportation. The mineral in this state requires to be crushed and prepared with sulphuric acid, which renders it soluble as a Superphosphate of Lime. When manufactured in this way, it is invaluable on the worn out farms of the older districts of this country.*

Bone-dust, guano, and the liquid manures of stables, are at present the chief sources of this substance to the farmer, and have been noticed under the head of organic manures.

Coal Ashes.—The ashes of coal consist principally of silica and alumina, which constitute over 86 per cent. of their weight. These substances are in a fine state of division, and give the ashes a great power of absorbing liquids and gases. Coal ashes also usually contain oxide of iron, carbonate of lime, sulphate of lime, magnesia, and minute quantities of silicates of potash and lime, and of phosphate of lime.

Though the ashes of different kinds of coal differ somewhat in composition and absorbent power, and are much inferior as manure to wood ashes, yet they are always of some service, more especially when employed to absorb and retain liquid manures and the soluble and volatile parts of organic substances.

* Superphosphate of Lime is now manufactured in Canada, and should be used by all farmers on old lands.

CHAPTER XIII.

CROPS.

Under this head we shall consider the bearing of the principles previously stated, on the plants ordinarily cultivated in British America, and shall notice the peculiar habitudes of these plants and their diseases and enemies.

§ 1. *Wheat.*

This, the first of our farm crops, is the *Triticum vulgare* of botanists. All the kinds cultivated in this country belong to one species, but of this there are two leading varieties,—the spring and winter wheat,—and under each, many subordinate varieties, produced by culture and selection.

Wheat requires to have in the soil a supply of both mineral and organic food in a well elaborated state. Hence it will neither thrive in a poor soil, nor in one the riches of which consist of vegetable matter in a crude or undecomposed state. It also very readily permits weeds or grasses to grow beneath its shelter. For these reasons, newly burned land, land that has been fallowed and manured with composted manure, or land that has been previously cleaned and manured with a green crop, is most suitable for wheat. On lea land it is very subject to rust, and also to the attacks of the Hessian fly, whose larvæ are generally present in the grass, and destroy the wheat which takes its place. The place of wheat in the rotation of a scientific farmer, must therefore be that assigned to it in the ordinary Scottish four-course rotation, viz., after a green crop and before grass, which is sowed with the wheat.

The organic part of the grain of wheat consists principally of gluten, albumen, starch, gum, sugar, oily matter, and the woody matter of the husk. Of these ingredients the most

important in reference to human food, are the gluten and albumen, which are also the substances whose elements are least easily obtained from poor soils. They are obtained from the richer kinds of manures; and their nitrogen,—the most difficult of their elements to procure, chiefly from the ammonia and nitric acid afforded by these manures aided by the atmospheric supply. It is also worthy of remark, that the percentage of gluten varies according to the amount of such rich materials in the soil. Hence the wheat of well manured land is not only more abundant, but yields bushel for bushel, more flour—and more nutritious flour, than that of poor land. The rich and well tilled soils of this country, produce wheat equal to that of any country in the world. The poor and worn out lands furnish inferior grain, milling badly, and yielding an inferior flour deficient in gluten.

The ash or earthy part of wheat is also of some importance, especially as for this the plant is entirely dependent on the soil; and though this part of the plant is comparatively small in quantity, yet its due supply is absolutely necessary to healthy growth.

More than one half of the ash of the straw of wheat consists of silica, an element sufficiently abundant in most soils; but it is to be observed that this element can be obtained only by the aid of potash or soda, which must therefore be present in the soil. Potash and soda are also required independently of the conveyance of silica. The ashes of 1000 lbs. of the grain of wheat contain 4½ lbs. of potash and soda; the straw contains a much smaller proportion. Wheat also contains in its ash, lime, gypsum, magnesia and common salt, but in small quantity. The ingredient of the ash of wheat which of all others is the most important, is bone earth or phosphate of lime, of which about 70 lbs. are taken by an ordinary crop of wheat from an acre of ground. This may appear to be a small quantity, but it must be borne in mind, that this substance is scarce even in fertile soils. It is chiefly the presence of alkalies and phosphates derived from the ashes of the woods, that causes wheat to produce so abundantly in new land.

It is also worthy of notice, that wheat, when permitted, sends its roots deeply into the ground, and therefore prefers a deep soil, or one that has been deepened by subsoiling and under-draining.

The facts respecting the composition of wheat stated above, indicate that manures containing nitrogen, phosphates and alkalies, are especially suitable to it. Such manures are guano, urine, animal refuse, ashes, and crushed bones.

Respecting the uses of the grain of wheat, it is unnecessary to say anything. It is not however very generally known, that the straw of wheat, if cut sufficiently early, and chopped with a straw cutter, is highly nutritive food for cattle and horses, and is much relished by them. In this country, wheat is generally cut too late, and the grain is thick in the husk and inferior in flouring qualities, and the straw is comparatively worthless. By cutting immediately after the grain is filled, and before the straw is wholly dead, both would be much more valuable and nutritious.

Wheat, though the most important of the grain crops, has, of late, acquired the character of being a precarious crop, especially in the older districts. It becomes therefore necessary to inquire into the diseases and blights to which it is liable. We may consider these in some detail, remarking in the first place that none of them are peculiar to British America, all of them being more or less experienced in most or all the countries in which wheat is cultivated.

1. *Rust.*—A reddish or rusty substance attached to the straw and leaves of wheat, in the end of summer or in autumn. When examined by the microscope, it is found to be a parasitic fungus or mould of the genus *Uredo*, whose minute and invisible seeds or spores are wafted by the winds, or borne to the plant with the water it absorbs from the soil, and taking root in the cells and vessels of the stem and leaf, weaken or kill it by feeding on its juices.

Its attacks are favored by the following causes: *First*,

damp and cold weather succeeding warmth, at the time when the straw is still soft and juicy; hence late grain is very liable to rust. *Secondly*, a deficiency of the outer silicious coat, which in the healthy state protects the surface of the straw, or an unnaturally soft and watery state of the plant. These unhealthy conditions may proceed either from poverty and want of alkalies in the soil, from the presence of too much crude vegetable matter, as sod or raw manure, or from a wet and undrained state of the land, which both causes the crop to be late and fills it with watery juices. *Thirdly*, It is highly probable that one inducing cause, is the accumulation of sugar and albuminous matter in the straw, and the inability of the plant, owing to the want of phosphates, to turn this sugar and albumen into the starch and gluten of the seed. *Fourthly*, it is probable that when the grain of rusty wheat is sown, or when sound wheat is sown in ground in which wheat has rusted in previous years, the crop may be more easily affected by the disease, because the spores of the rust fungus may be attached to the seed or may be in the soil.

The best preventives of rust therefore are: *First*, healthy seed; *Secondly*, early sowing; *Thirdly*, draining; *Fourthly*, abstaining from sowing wheat in lea land; *Fifthly*, preparing the soil in such a manner that it shall be sufficiently rich, yet not filled with crude vegetable matter, and paying attention to the supply of alkalies and phosphates.

2. *Mildew.*—This term is often used in this country as synonymous with rust; but properly speaking, mildew is the effect of the growth of other fungi, usually of the genus *Puccinia*, which are however not dissimilar in their habits from the rust fungi; though in this climate less destructive.

3. *Smut or Bunt.*—This also is a parasitic fungus, *Uredo fœtida*, which grows *within* the grain, and converts its substance into a dark colored fetid mass of spores or mould balls, which under the microscope look like rough berries, and are filled with the minute dust-like seeds of the smut. Its mode of propagation is pretty well understood and

easily guarded against. When smutty grain is threshed, the infected seeds are broken, and the smut being of an adhesive nature attaches itself to the sound grain, and when this is sown, the fibrils of the smut pass upward though the stem, and infect the crop. In like manner, if sound grain be put into bags or boxes which have contained smutty grain, or if it be threshed on a floor on which smutty grain has been lately threshed, it will be infected. These causes of the disease should therefore be avoided by all prudent farmers.

In addition to this however, the seed wheat should always be washed before sowing, that any particle of smut which may happen to be attached to it may be removed. In this way the increase of the evil may be effectually guarded against.

"It is quite certain, that the disease may be at any time propagated by rubbing sound wheat against that which is infected by the fungus. If then the seed be sown in this condition, the result may be easily predicted. The method also of counteracting the evil at once suggests itself. It is merely to cleanse the wheat which is about to be sown, from all the smut which may have attached itself to it, by reason of its adhesive character. The principle of effecting this object clearly must be, to use means to convert the oily matter which causes it to stick obstinately, into a soapy matter which will allow it to be readily washed off. Chemistry here comes to our aid. An alkali will convert oil into soap, and this is the basis of all effectual *dressing*, as it is called, of seed corn. Almost every district has its peculiar dressing, but the best are merely modifications of this principle. Whatever other ingredients may be used, the effective constituent is some alkaline matter in the form of a ley. Lime, which possesses alkaline properties, has accordingly not unfrequently been resorted to; it must not however be too much slaked in using, or it loses these properties and thus often fails. Common potash and substances containing ammonia, for example, the liquid excrements of animals, have been adopted for remedies. Some persons employ brine, sulphate of copper (blue vitriol),

arsenic and other things not possessing alkaline properties. Whenever these methods succeed, it cannot be for the reasons advanced, but it may happen that they destroy the vegetative powers of the seeds of the fungus, though they still remain fixed to the grain."*

It must be observed, that it is not merely steeping but *washing* that is necessary to cleanse the grain, and the washing process should be aided by some alkaline substance. Solution of potash, ley of wood ashes, and stale urine, are the best washing fluids; and the grain should be stirred in them for some time, and the liquid carefully drained or poured off, after which the grain may be dried by stirring slaked lime, gypsum or dry wood ashes with it. This method is more certain than the common steeping in brine or blue vitriol.

The same precautions are useful in guarding against the *Dust Brand* or dusty smut, *Uredo segetum.* This however is less dreaded by farmers, and there is reason to believe, that its seeds or sporules are more often present in the soil than those of the true smut, as they are scattered about by the winds in autumn.

4. *Ergot.*—This is an unnatural enlargement of the grains of wheat, by which they are converted into a black spongy substance about twice the length of the ordinary kernel, and of a very poisonous nature. It is uncertain whether it is merely a diseased growth or a parasitic fungus substance, though the latter seems the more probable view.

Ergot does not usually destroy any large proportion of a crop, but when not attended to, may make it useless or deleterious by its poisonous properties. When observed, the grain should be sifted through sieves sufficiently small to retain the enlarged ergot grains. This should be attended to, whether the grain be intended for the mill or for seed.

It is said that low moist lands are more subject to ergot, and that in such lands the disease may be removed by thorough draining. This view, which seems to be confirmed by experience in this country, deserves the attention of farmers whose fields are infested by this nuisance.

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* "Blights of the Wheat."—London.

5. *The Wheat Midge or Weevil, Cecidomyia Tritici* and *C. cerealis* of naturalists, has in recent times been the most destructive of all wheat blights. It is improperly called weevil; the weevils, properly so called, being a tribe of beetles the young of which destroy corn in granaries. It is only by a careful study of the habits of a creature of this kind, that we can hope to counteract its ravages.

The observations of naturalists in England, where the creature has been much longer known than in America, have proved that the destroyer is the larva or grub of a minute midge, which deposits its eggs in calm summer evenings, on the chaff scales, whence the little grub when hatched creeps inward to the young grain, on whose juices it feeds. When full grown it descends to the soil and passes the winter in the ground. The following experiments and observations made many years ago, and I believe the first which clearly established the facts of the case, will suffice to give a view of the habits of these creatures. They refer to the *C. Tritici.*

A quantity of the larvæ were procured, full grown and in that motionless and torpid state in which they usually appear when the grain is ripe. A portion of these larvæ were placed on the surface of moist soil in a flower pot. In the course of two days, the greater number of them had descended into the ground, previously casting their skins, which remained at the surface.* I afterwards ascertained that they had penetrated to the depth of more than an inch, and were of a whitish color, softer and more active than they had previously been. The fact is thus established, that these apparently torpid larvæ, when they fall from the ripe wheat in autumn, or are carelessly swept out from the threshing floor into the barn yard, at once resume their activity, and bury themselves in the ground.

The larvæ thus buried in the ground, were allowed to remain undisturbed during winter and spring, the flower-

* Some observations of Dr. Fitch, and Mr. D. J. Browne, render it probable that the skin is sometimes cast in the ear before descending to the ground.

pot being occasionally watered. About the end of June they began to re-appear above the surface, in the winged form; the little grubs creeping to the surface, and projecting about half their bodies above it, when the skin of the upper part burst and the full grown winged midge came forth and flew off. This completes the round of changes which each generation of these little creatures undergoes, and we have thus actual evidence of each stage of its progress from the egg to the perfect insect.

The perfect midge is a pretty little creature, its body being of a bright yellow color like that of the larva, its two large wings perfectly transparent with iridescent reflections, its eyes black, and its antennæ or feelers long and jointed; the male is smaller than the female, and has its antennæ ornamented with hairs. The flies are most active in calm and warm evenings, when they may sometimes be seen in clouds over the wheat fields. British observers say, that the female deposits her eggs within the chaff; but here, they appear to be generally deposited without.

However we may dread the destructive powers of the midge, we cannot withhold our admiration from the singular instincts with which it has been endowed. The female insect depositing her eggs where food and shelter are provided for the young brood; the larvæ when shaken from their summer abode by the storms of autumn, at once entering on a new and untried life in the soil; and the chrysalids working their way to the surface in the ensuing summer, to assume their winged state in time for the new crop of wheat, display a series of adaptations which may convince us, that, however annoying in the mean time to us, a creature so gifted cannot be without important uses in the economy of nature.

It is evident, that if no check were opposed to the increase of these creatures, they must ultimately in every country where they occur, consume the whole or nearly the whole of the wheat crop. There are however such checks, some in natural causes, and others in expedients which may be adopted by man.

In Europe the larvæ of several small parasitic insects

prey on those of the midge, and no doubt greatly limit their increase.* Dr. Fitch has observed one such enemy of the midge in the United States. In this country, in cold and bare winters, it is probable that many perish; though it is quite an error to suppose that wet weather can kill the larvæ when in the ground. Moisture in the ground, indeed, appears to be essential to their life. Windy or stormy weather at the season when they are on the wing, must also greatly interrupt them in depositing their eggs. Accordingly they are observed to be most abundant in *sheltered* situations, and elevated and airy places are less liable to suffer from their attacks.

It appears from what has been said above respecting the habits of the midge, that during the greater part of its existence it is beyond the control of the farmer. He cannot prevent it from depositing its eggs, nor can he extract the larvæ from the growing crop; and in the ground in autumn and winter, they are almost equally beyond his reach. *He can however destroy as many of them as he can house with his grain.* In this country, as in Britain, the full grown larvæ remain in the chaff until the grain is ripe, or until they are shaken to the ground by the first violent storms of autumn. When grain is observed to be infected, it should be attentively watched and cut so soon as this can be done without serious loss. In this country, wheat is often left till it is too ripe; over ripe grain being much inferior to that which is earlier cut in the quantity and quality of its flour; and when the weevil is present, there is a double gain in early cutting. It would also be advisable whenever it is possible, to reap, rather than cradle, the grain, in order to avoid shaking out the insects. The wheat should be threshed on a close barn floor which will not allow the larvæ to fall through, and when the grain is cleaned, *all the chaff and dust separated from it should be burned*, or if the chaff be saved for fodder, it should be *kept dry*, and none of it allowed to be mixed with the litter or thrown on the manure heap.

* See a paper by Mr. Billings in the Canadian Naturalist, vol. 1, p. 450.

This method costs little trouble, it causes no loss, and if faithfully followed out, would greatly diminish if not altogether prevent the losses occasioned by the weevil. It is worthy of attention, even in cases where the crop is only affected to a small extent. The midge often destroys a fifth, fourth, or even a third of a crop, without exciting much attention, and it is only when almost total loss ensues that great alarm is excited; but even these partial losses are not of small importance, and by destroying the larvæ in a season in which only a fourth of the crop is lost, we may perhaps prevent a total loss in the next season. It is true, that when this precaution is neglected, Providence, kinder to the farmer than he is to himself, may, by some of the natural causes already mentioned, check the increase of the destroyers; but this will not always occur, and certainly furnishes no excuse for neglecting the means of safety which are placed within our reach.

As an illustration of the saving which can be effected by destroying the larvæ which are housed with the grain, I may mention that the friend who furnished me with specimens for experiment, informed me that from the wheat of eight acres he had obtained about *four bushels* of larvæ of the weevil. After making a large deduction for dust mixed with them, this quantity must have contained about 150 millions of the insects. If these insects, instead of being burned, had been scattered over the ground, they might if the ensuing season had proved favorable to them, have destroyed the greater part of the wheat crop on the farm.

Various other expedients for the destruction of the midge have been proposed or adopted. When the flies are observed to be on the wing they might be prevented from depositing their eggs by kindling fires on the windward side of the field, or by agitating the grain by stretched lines carried by men or boys, in the calm evenings when the midges are most active. These however are clumsy and troublesome expedients, though, when they can be attended to, they may do much good. It is also probable that if the ground were deeply ploughed, after the larvæ had fallen upon it in autumn, they might be too deeply

covered to permit of their escape in the spring. In the ordinary system of rotation however, this could not be done without losing succeeding hay crops; and it is doubtful if it would be very effectual. Perhaps the most effectual remedy ever proposed, is that of discontinuing the culture of wheat for a year, and thus depriving the midges of the necessary food for their larvæ. This is however an expensive expedient, and it requires the consent of all the farmers in the district affected. In the great majority of cases, it might be rendered altogether unnecessary, if the method of destroying the larvæ already described were generally adopted.

The most popular remedy hitherto tried has been late sowing in the case of spring wheat, and early sowing in that of winter wheat, so as to have the wheat in blossom too late or too early for the insect. This, however, in the case of spring wheat subjects the grain to rust, and necessitates the use of early varieties of grain, which are not usually so heavy or productive as others. In the case of winter wheat, it renders it more liable to the attacks of the Hessian fly. It is also probable that in a few years the habits of the creature and the date of its appearance will *change to suit the lateness or earliness of the grain* which forms its food, and then the late sowing will prove quite ineffectual. It is also deserving of notice, that bearded varieties suffer less than the bald, as the awns obstruct the insects in depositing their eggs.

The facts above stated may be summed up as follows:

(1.) The insect deposits its eggs on the grain about the time when it is in flower, and usually in the evening.

(2.) The larva when hatched attaches itself to the young grain and prevents its growth.

(3.) When full grown it becomes stiff and torpid, and if left long enough falls to the ground.

(4.) It buries itself in the ground and thus passes the winter.

(5.) In spring, it emerges from the ground as a perfect insect, in which state, if the weather be favorable, it seeks the growing wheat for the purpose of depositing the germs of a new brood.

Lastly, though there are many partial remedies, the only sure one is to *cut early and destroy all the grubs found after threshing the grain.* To ensure safety, this should be kept up as regularly as the washing of seed wheat to avoid smut.

5. The Hessian fly (*Cecidomyia destructor*) is a relative of the wheat midge, and at one time threatened, like it, to destroy the culture of wheat. Its ravages have however in late years materially diminished. It attacks the stems of the young or half grown plants, establishing itself at the base of the shoot or in the joints, and when abundant wholly destroys the crop. The eggs, according to the best observations, are deposited on the leaves, whence the little larvæ or maggots when hatched make their way downward between the leaf and the stem. There are two broods, one produced from eggs deposited (in winter wheat) in autumn, the other produced from eggs deposited in spring, and attacking both spring and winter wheat. The best remedies are careful tillage and preparation of the ground, and abstaining from sowing on lea land, wheat grown on which is especially liable to be injured. Burning the stubble and ploughing it under, rolling the young wheat, mowing it in autumn, or cutting it in spring, and late sowing, are all remedies that have been recommended, especially in the case of winter wheat. There can be no doubt however that the principal cause of the excessive multiplication of this insect is the want of any rational system of rotation of crops; and the introduction of this, usually arrests its ravages.

Several parasitic insects prey on the larvæ of the Hessian fly and greatly diminish its numbers.

6. *The Army Worm,* (*Leucania extranea,*) is a naked caterpillar of the cut-worm tribe, of a gray color, with black and brown bands. Their native haunts appear to be meadows and similar places, where they devour the leaves of grass, but in some seasons they migrate in immense numbers to the grain fields and strip the grain of its leaves. When full grown they pass into the pupa state, under clods and in the ground, and emerge as plain gray moths.

The injuries inflicted by these creatures are usually quite local. The only way of arresting their progress seems to be by digging narrow and deep ditches across their path, and killing them as they accumulate in these ditches.

7. Wheat is attacked by the larvæ of many other insects. Those of certain little flies of the genus *Chlorops* establish themselves in the stem. Other flies of the genus *Oscinis*, in their larva state, eat the young grain. Several beetles, moths, and neuropterous insects also prey on it. None of these have however been so destructive as the midges, and the habits of many of them are very imperfectly known.

8. *The Oat Aphis* is a little plant louse which appears in vast numbers on wheat, oats, and other grains, and often causes much alarm, and inflicts some injury on the crop, though not usually to a great extent. It appeared in great abundance in Canada in 1861.*

§2. *The Oat.*—(*Avena sativa.*)

The organic part of the kernel of the oat very much resembles that of wheat. Oatmeal contains 10 to 18 per cent. of gluten or an analogous substance, and is scarcely inferior to wheaten flour as an article of nutriment. In its inorganic ingredients or ash, it differs from wheat in proportion though not in kind; and it requires from the soil nearly twice the amount of inorganic matter required by wheat. It is therefore a great mistake to suppose that the oat is less exhausting than wheat, if both straw and grain be removed from the soil. The oat however can take nourishment from raw and undecomposed vegetable matter, such as sod, peat, &c., from which wheat can obtain little nutriment.

As in the case of wheat, silica and alkalies are the principal ingredients of the ash. Both are however in larger quantity than in wheat. The oat also carries off from the soil a larger proportion of gypsum; hence it thrives in gypseous soils, or in sour soils which contain sulphuric

* See a paper by Dr. Lawson in Canadian Naturalist, vol. 7.

acid, after they have been limed. The quantity of bone-earth required by the oat is nearly the same in proportion with that required by wheat.

The above remarks show the proper place of the oat in the rotation, to be that which it usually bears in the ordinary Scottish rotation; viz: the first grain crop after ploughing up the sward. It is well fitted for this, not only by its power of extracting nutriment from the decaying sod, but also by its dense shade, which prevents to a great extent the growth of weeds and grasses. This last character, as well as its great demands on the soil for inorganic food, unfit it for sowing with grass seeds, or occupying the place of wheat in the rotation.

It is barbarous farming to extract two successive crops of an exhausting grain like the oat from any ordinary soil, or to take a crop of oats and then let the land run out into grass. Nothing but dire necessity can excuse these practices, which are unhappily too prevalent. The manure produced from the oat straw, or its equivalent, should in all cases be restored to the soil in the succeeding year for a green crop. If this be done, the soil is improved, rather than deteriorated.

Our country is well adapted to the growth of oats, and this applies even to those parts of it in which wheat is uncertain. Oats must therefore always form a prominent object of attention to our farmers; more especially in the colder and less productive districts.

Few crops require more frequent changes of seed than the oat. When cultivated for a number of years in the same soil in our climate, it acquires a thick outer husk at the expense of the kernel, and becomes more liable to dust-brand. Experience has proved that the best change of seed is that imported from Scotland; and no oats are superior for this climate to the early varieties of that country, as the early Angus, Hopeton, Dutch, &c. They are thin-skinned and heavy, and bear cultivation here for five or six years, before they acquire the appearance and defects of run-out oats. Indeed for two or three years after importation, they greatly improve in size and appearance, though probably not in actual value.

The Black or Tartarian oat is much cultivated in this country, but its only good quality appears to be earliness. It is inferior as a mealing oat both in quantity and quality, and though in some quarters a preference is given to it as food for horses, there can be no doubt that the white is more nutritious. Much loss is also sustained in this country by the cultivation of those lean, chaffy and bearded oats, that have been run out by long cultivation, and mixed by carelessness with better varieties.

The dust brand and the grubs of the Harry-long-legs (*Tipula*) often injure the oat crop, but I am not aware that they have ever become so destructive as to call for any special attention on the part of the cultivator.

§3. *Rye.*—(*Secale cereale.*)

The grain of rye does not differ very materially in its composition from that of wheat. It contains however more sugar and less gluten; and the gluten is of a somewhat different nature, at least in its mechanical properties, and is less fitted for the production of a well-raised bread. Rye takes less from the soil than wheat. The difference is principally in the straw, which contains less lime, silica, and bone earth than that of wheat, but a little more gypsum. The ash of the grain differs very slightly from that of wheat.

Rye prefers light soils, and may be made very useful in bringing in light ground unfit for the growth of wheat. It also forms a substitute for wheat when the latter grain appears to be in danger of being destroyed by weevil; but in ordinary circumstances, it should not be sown on ground capable of producing wheat, being much inferior to that grain as an article of food. Rye straw is of little or no value as fodder; but is excellent for thatching, collar-making, and basket-making, and makes tolerable hats.

It is said that rye has occasionally suffered from the wheat fly, but slightly. Its worst enemy is the ergot, a fungus-like enlargement of the grain, which, like the ergot of wheat, renders it black and poisonous. When the ergot is

observed, it should be carefully sifted from the grain before grinding. The principal inducing cause of ergot appears to be too great moisture in the soil; and where this is the case, the culture of rye should not be persisted in, when the ergot is found to appear constantly or often in it.

§4. *Barley.*—(*Hordeum vulgare.*)

The grain of barley much resembles in its composition that of wheat, but it contains less gluten and more starch and sugar. It is therefore less nutritious, though in wholesomeness it yields to no other grain. In many parts of the country, barley is little known except for its use as pot-barley, and its value as a material for the manufacture of alcoholic liquors. Its culture as a bread corn, should, perhaps be more widely extended. To most persons the flavor of barley bread is very agreeable, and barley-meal pottage is certainly superior to that of Indian meal or rye flour. Barley is also an excellent substitute for wheat, when the latter is in danger from weevil. It is a very sure crop, and very early; and suits admirably for sowing with grass seeds. Its true place in the rotation is the same with that of wheat. It may however be sown in lea land, though it is not so suitable for this as the oat.

Barley takes rather more from the soil than wheat, and the excess is principally in silica, bone earth, lime, alkalies, and gypsum. It is therefore a mistake to suppose, that a good crop of barley does not require a soil in good condition, but as barley sends its roots much along the surface and not to a great depth, it is less dependent on deep tillage than wheat. Alkalies and especially soda are highly favorable to its growth, and it prefers light and loamy soils.

§5. *Indian Corn.*—(*Zea mays.*)

The composition of the grain of Indian corn is very variously stated by different chemists. According to Salisbury of New York, quoted by Norton, it contains 60 per cent. starch, 10 per cent. fatty matter, and 12 to 16 per

cent. gluten and analogous substances. This would give it a very high value as an article of food, especially for fattening stock. In this climate, Indian corn requires a light, deep soil, and a good supply of rich manure. Gypsum should be strewed on the top of the hills or drills, both as a direct manure, and to prevent the escape of the ammonia from the manure beneath. The most convenient place of corn in the rotation is as a green crop, since the treatment which it requires and its effects on the soil are not very different from those of the turnip and carrot. Good corn may however be raised in lea land, and also after green crops in place of wheat, but in both cases manure is required in addition to that already in the soil. It is better to plant corn in drills, like turnips, but farther apart, than in hills. Nothing is gained by having the plants crowded; they require much air and light. In stiff soils they should be well earthed up, or the seed may be planted in the tops of the drills, but in light land it should be planted on the level. Frequent hoeing is very beneficial, as also cleaning and earthing with a light plough or cultivator. Pumpkins are often planted with corn; many good farmers, however, believe that the gain in pumpkins scarcely repays the loss in corn. This must depend on the degree to which the leaves of the pumpkins deprive the corn of air and light, and on the impediments which the vines offer to the proper culture of the corn.

It is useful to cut off the feather or bloom, the male flower of the corn, after it has served its purpose in fertilizing the ear. This should be done when the beard or tassel of the ear begins to wither, but not before; and as few large leaves as possible should be cut off with the top, as all the leaves are useful in aiding the growth of the ear. The tops make good fodder, and when deprived of them the corn is less likely to be broken down by autumnal storms.

Corn is subject to the attacks of grubs which burrow in the stalks, after the manner of the larvæ of the Hessian fly in wheat. The easiest remedy appears to be sowing sufficiently thick to allow spare plants for the grubs. When, however, time can be spared to pull up and destroy every

plant that shows by the fading of the leaf the presence of the grub, the labour will be repaid by the diminished number of grubs in the ensuing season. The seed is also sometimes destroyed by squirrels, birds, &c. This may be prevented by steeping the seed in anything that makes it distasteful to these depredators. Steeping in urine, soft soap or nitre, and drying with lime or gypsum, are said to be serviceable; but smearing with tar has also been practised, and is stated to be more certain.

The meal from corn raised in this country is finer and more delicate in flavour than that from Southern and Western corn. This should cause it to bring a higher price; and should in connection with the productiveness of the crop, commend its culture to all farmers who have the sandy or loamy soils which it prefers. Even if too late to ripen, it is valuable for fodder, if cut immediately after the frost strikes it.

§6. *Buckwheat.*—(*Polygonum fagopyrum* and *P. tataricum.*)

The extended culture of this plant cannot be considered as an indication of improved or prosperous agriculture; since this grain is generally a substitute for others, or a refuge from the want caused by impoverishment of the ground. Buckwheat, however, is a grain of some value, and, if properly used, need have no connection with bad farming.

The kernel of buckwheat contains from 6 to 10 per cent. of gluten, and 50 of starch, with 5 to 8 per cent. sugar and gum (*Norton*). It is, therefore, inferior in nutritive power to all the grains previously noticed; though, still, a very valuable article of food. A portion of the inner husk is usually ground with the flour; giving a dark colour, and bitter taste. When this husk is entirely removed, the flour is pure white, and so dense as to resemble rice flour, or potato farina; and, either in bread or cakes, is a light and agreeable article of food. Of course the quantity of this fine flour is much less than that of the coarse kind;

but the refuse is useful for fattening hogs; and if good flour were more generally made, its use would be extended and its price enhanced.

Buckwheat does not make great demands on the soil. Its large leaves obtain a great part of its nutriment from the air; and it requires but a small proportion of mineral matter. Hence it can be successfully cultivated on very poor soils, though it certainly thrives better on those that are rich. From the dense shade which it produces, it is an admirable exterminator of weeds; and hence, makes a good preparatory crop for weedy soils or poor grass land. The scattered seeds of the buckwheat itself are, however, apt to be troublesome in the succeeding crop. In England and the continent of Europe, buckwheat is often usefully employed in reclaiming poor soils, by ploughing it in when green. A large amount of vegetable matter is thus given to the soil; and I have no doubt this would be found useful in bringing in light and worn-out soils in this country.

The stems and leaves of buckwheat, cut green, make good summer food for cattle; but are less nutritious than clover. Large heaps of buckwheat husks are sometimes seen near mills. They should be composted, and applied to the land; and would be found to be excellent manure.

§7. *Beans and Peas.*

These plants are remarkable for the large amount of nutriment which their seeds contain, and which is greater even than that of the best wheat or oats. Hence, though they cannot in ordinary circumstances form so large parts of the crop as the cereal grasses, they are important objects of the farmer's attention.

The *French*, or *dwarf kidney beans*, (*Phaseolus vulgaris, var. nanus,*) are very valuable as a green crop. Their produce is not very large, but is highly nutritive; and they have the merit of being the best table substitute for the potato. They require compost manure, and to be kept clean from weeds. They may very well occupy a portion

of the drills prepared for turnips, as the same manures and mode of culture suit them; and the time of sowing is also the same. French beans should not be in the ground till the buds of fruit trees are bursting, as they are very liable to be nipped by late frosts, or rotted by cold damp weather. The China, white Canterbury, or small white calavança, are the best for this climate. The imported calavanças are rather late; but by picking the earliest ripe pods for seed, they soon become sufficiently early. Kidney beans contain 23 per cent. of legumin, a substance analogous to gluten, and 43 per cent. of starch (*Johnston*).

The *horse bean* (*Vicia faba*), may be cultivated in the same manner with the French dwarf, but must be sown early. It is used exclusively, at least in the dry state, for the food of animals, especially horses and hogs. It is more nutritious than the oat, and better for working horses; though at first it is often difficult to induce them to eat it. The small horse or tick bean of England, thrives well in this country; though some farmers here prefer the early cluster, or some other variety of the broad horse bean, as being more productive, and ripening equally well in this climate. The straw of these beans, if chopped or broken up, is excellent fodder, little inferior in nutritive properties to ordinary hay.

Beans of all kinds require from the soil a large quantity of potash and lime, principally for their stems. Manures and composts, containing much of these substances, are, therefore, especially adapted to them.

The *Pea* approaches very nearly to the bean, in point of nutrition, and perhaps excels it in fattening power; and its straw, or haulm, if saved in good condition, is stated to be little inferior to meadow hay. The straw of the pea contains a large proportion of lime; and hence, this substance, or composts containing it, form very proper top-dressings for a pea crop. The pea occupies a different place in the rotation from the bean; for, though the dwarf varieties may be cultivated in drills as a green crop, it ordinarily thrives very well if sown broad-cast, in any tolerably rich land that is not overrun with weeds. Peas

have, indeed, no regular place in a rotation, and are somewhat uncertain. They are therefore rather giving way, in the best farming districts, to the culture of beans and turnips. The pea often suffers much from the pea-worm, which is the larva of a small species of moth, or in other cases of a little beetle (*Bruchus pisi*). No treatment applied to the seed can avert the attacks of these creatures, since the eggs from which the larvæ are produced are deposited by the parent insects in the blossom, or young pod. The best remedy is, to sow very early; and it seems worthy of enquiry, whether early peas, sown in early spring, might not be gathered in sufficient time to permit a crop of buckwheat to be taken from the same ground. At all events, buckwheat might be sown and ploughed in, to enrich the soil.

§8. *Turnips, Carrots, Mangel Wurzel, &c.*

These, in most of the countries of the northern temperate zone, form staple green crops; and probably contribute as much to the money returns of the farmer as any other crops. In this country, as yet, their capabilities have been very imperfectly tested; though there can be no doubt that their culture is largely on the increase. In reference to these crops, Johnston remarks, with much truth, "To raise them, the farmer must prepare, must save, and must husband his manures; he must feed his cattle better, and will thus be led to improve his breeds of stock; while the better harvests of grain he obtains after the green crops, will make these grain crops themselves more profitable, and therefore objects of more useful attention. The spread of green crops in England and Scotland has been invariably the prelude to agricultural improvement, and to an amelioration, not only in the practice, but in the circumstances also of the farmers."

All these roots contain a large proportion of water; and their nutritive portion is made up of albumen, sugar, gum (pectin), and starch. These substances are present in various proportions, according to the kinds of roots culti-

vated, and the nature of the soil and manures. All of these root crops require from the soil much potash, soda, lime, bone, earth, and gypsum, as well as some vegetable matter; and the manures intended to afford these substances should, when practicable, be in the form of well rotted composts. Long manure will rarely afford a heavy crop.

As the turnip is the most important of these roots, and it is very desirable that it should take its proper place in our provincial agriculture, I quote from Judge Peters' "Hints to the Farmers of Prince Edward Island," the following directions, which are admirably adapted to this country, and give also useful information as to the culture of other green crops:

"Turnips are generally sown in that part of the rotation which closes one course and commences another; and in this Island it will in general be found convenient to sow them after oats, sown on lea. On newly burnt lands there are few weeds, and excellent crops may be raised with little labor, by merely scattering the seed and hoeing it in; but with this exception, they should always be sown in drills, under which system three acres can be cultivated with less labor than one acre broad-cast. The land intended for them should be well and deeply ploughed in autumn, and cross-ploughed in the spring, then harrowed and rolled to break the lumps. If the land is foul with couch, have it well cleaned, or the turnip crop will be a failure, or cost more to keep clean than would have cleaned the land before they were sown. Next open the drills; thirty inches apart is the best distance for ordinary culture, as it gives room for the plough and horse-hoe to work freely between the drills without injuring the plants.

"When the drills are opened, then cart in your manure, which should be short, and make it in small piles, so that it can be regularly spread in the drills. By making the piles so that they will spread into the three drills in which the horse walks and the cart wheels run, you will spread it more evenly, and with less labor, than from the larger piles, in which I often see it deposited. As soon as the manure

is spread in the drills, and before the sun can dry it, split the drills with the plough, which will cover the manure and make a ridgelet over it, then run a light roller lengthways along the drills, so as to flatten then on the top, and drill in the seed at once; it is very important that it should be done as soon as the drills are rolled, for the ground is then fresh and damp, which causes the seed to vegetate quickly: whereas if you leave it, the tops of the drills get dry, the seed is longer coming up, and the plants grow more slowly. I frequently see persons waiting for days, until the whole of the land is prepared, before they sow. This is a very bad practice, because not only do the drills become dry, but the weeds begin to shoot before the seed is sown; and when the plant comes up, it finds the weeds up before it, and is consequently smothered, and is much more difficult to hoe and clean. The least you can do for the turnip is to give it fair play and a fair start with its numerous weedy competitors; and, therefore, make it a rule to sow in the evening, or, at furthest, the next morning, every drill that has been dunged and covered during the day. Some spread the manure broad-cast, and plough it in with the second ploughing, and raise fair crops; but by putting it in the drills, the whole strength of the manure is given to the roots of the turnip, and therefore, must promote its early growth more than when spread over a large space of ground. When the manure is ploughed in broad-cast, I think it should be done in the fall; a method which seems to produce excellent crops, and saves labor in the spring, when time is of most value to the farmer.

"As to the best time for sowing Swedes, there is much difference of opinion; they may be sown from the 20th of May to the end of June; they continue to increase in weight until the frost compels us to pull them, and therefore, the earlier they are sown, the heavier will be the crop. When sown in May, I have always found them escape the fly; but the best protection against this insect is thick sowing—never sow less than three lbs. of seed to the acre, and you will seldom be without sufficient plants after the fly has done its work. Aberdeen Yellows may be sown from the first to the end of July.

"Hoeing and cleaning are the most important part of turnip culture: manure as heavily as you please; if this is neglected, or carelessly or imperfectly done, you will not have a good crop; a few days' delay, carelessness, or inattention now, will make a difference of hundreds of bushels per acre. There is no crop on your farm which can so ill bear delay at this time as your turnips, and unless you can afford to throw away the labour you have expended, and to forego the benefit of a good supply of turnips for your stock, do this *when it should be done*, and *do it well.* If you are short-handed, let every man, woman, and child, who can lift a hoe or pull a weed, go to work in earnest, and the job will soon be accomplished; and what is more, your children will become expert at turnip culture, on which all successful farming in this Island will, before long, depend: and remember that a good turnip-hoer never takes his eye from the ground, until called to dinner; recollect this yourselves, and impress it on the children, and there will be no stopping to talk, nor ceasing work to gaze at every passer by, by which so much time is often lost. The method I have found best in hoeing is this: as soon as the leaves are between two and three inches long, run a plough between the drills, taking away the earth on each side to within about two inches of the plants; this will make a little ridgelet between each drill, and cover up all the weeds: and if the horse-hoe is run through about a week afterwards, they will be found quite rotten and form a good manure for the land; (some use the horse-hoe only, but if there is much yar and weeds, the plough makes the best work.) Then set to work with the hand-hoes, and thin the plants five inches apart: when the plants are a good size, and the leaves begin to touch each other, a second hoeing must be given, cutting out every other plant; this will leave them ten inches asunder, taking away at the same time any weeds that are between them. This second hoeing is very quickly done. If the land is very weedy, the horse-hoe should be run between the drills once before the second hoeing and once after, and this will complete the work.

"Besides the manure covered in with the plough, small quantities of stimulating manures, placed close to the seed, are of great benefit to the crop; a small quantity of ashes run with the hand along the tops of the drills just before the seed is drilled in, will cause the young plant to grow more quickly, and get sooner beyond danger from the fly: twelve or fifteen bushels are sufficient for an acre; more than twenty is waste. When the manure is ploughed in in the autumn, if you have a compost of mud and lime, or mud and ashes, to apply to your turnip land, in addition, the best way of doing it is, after the ground is ploughed in the spring, cart on and spread twenty to twenty-five loads of the compost, then harrow and roll, and then throw the land into ridgelets, with the plough, thirty inches apart; this gathers the greater part of the compost which has been spread into the drills, and within reach of the suckers of the turnip; then roll the drills and sow the seed. Night soil and bones are excellent helps to the crop—the mode of applying them has been already pointed out.

"*Pulling.*—Few directions need be given about this part of the business. The tops and tails should be cut off close to the turnips, or they will not keep so well. Some persons advise the tops to be hauled off and fed to the cattle on other fields. I have tried this, and am convinced it is a very bad practice. In the first place, as food, they are scarcely worth the labour of hauling off; they will keep cattle alive, but if they happen to be fat, they will reduce their condition; and if the milch cows get them, the butter will be unfit for market. But the great objection to removing them is, that it robs the land of what ought to be left to feed the succeeding wheat crop. A heavy crop of turnips is exhausting. In Britain, a portion of the turnips is consumed on the land, by sheep. Our climate will not permit this; therefore, as we have to remove the turnips, we should at least leave the tops. If you wish to feed them, and there is time to do so before ploughing, let them be eaten where they grew; or if not, plough them in, and decaying in the soil, they will enrich the land; whereas removing them is not only a waste of labour, but your wheat crop will reproach you for having done so.

"*Storing.*—Some complain of turnips being difficult to keep; those who find them so keep them too close: with proper management there is no difficulty in keeping any quantity. They should be put in piles in the field when first pulled, and covered with tops or straw, and a little earth. Here they will sweat a little. A dry day should be chosen to cart them to the root-house. My root-house is dug four feet deep, and then the roof pitched from the earth, and covered with seaweed and earth, well sodded over; the floor formed of slabs and longers, raised six inches from the bottom, and divided into three divisions. It will contain about two thousand five hundred bushels of roots, and I generally fill it full, and have never lost any turnips. In the top there is a chimney, which is never shut, night or day, during the winter; the vacancy below, and the partitions, allow all the confined air to ascend, and as it is constantly escaping through the chimney, no frost comes down. Any one who will ventilate his root-house in this way, will find the turnips as sound in June as when first put in. The situation of the root-house is a matter of importance; it should be attached to the barn, and entered from the barn; this will save a deal of labour in carrying them to the cattle during winter. Some store them in their cellars, which is the worst place that can be selected, as they are generally too hot and close to preserve the turnips, too far from the barn for convenience, and the gas which escapes from them renders the air of the house unwholesome.

"The Swedish turnip appears to be the best suited to this climate, especially on account of its property of keeping well in winter. The *mangel wurzel*, however, is, of all green crops, the best for milch cows. It produces a large quantity of milk without communicating to it any disagreeable flavor, and it keeps remarkably well in winter. The mangel wurzel transplants well; and its thinnings may be very properly used to fill up any gaps that may occur in turnip drills. It requires a somewhat stronger and deeper soil than the turnip, and in light soils the yellow globe variety will be found more profitable than the common long red.

"The *Carrot* is also a most profitable and sure green crop, especially in the lighter kinds of soils, and is admirably adapted for the winter feeding of working cattle and horses. The long white is the most productive variety; the long orange and Altringham the next; but the most delicate and nutritious for table use is the red horn.

"The *Parsnip* is well deserving of culture as a field crop. It thrives in the heavier kinds of soil, and yields a large quantity of very nutritious roots, which should be left in the ground during winter, and may be dug in early spring, at a season when little succulent food can be procured for stock. They would form an admirable resource in case of deficiency or loss of other roots stored in autumn. The carrot, parsnip, and mangel wurzel should be sowed as early as possible. I have even sowed them on a small scale, in autumn, with success. The turnip will do much later, and good Swedes have been raised in this province from seed sown in the middle of July. It is generally wiser, however, to sow much earlier, if there be any chance of protecting them from the turnip beetle or "fly."

"The carrot, parsnip and mangel wurzel suffer little from insects, and are very sure crops; but the turnip has two very troublesome enemies,—the turnip flies (two species of *Altica*), and the caterpillar of a moth which attacks the leaves in autumn. Against the ravages of the fly, the following expedients may be adopted. *First*,—late sowing, the fly being most destructive in May, and the early part of June. *Secondly*,—abundant seeding, which enables the plants to start more vigorously, gives a better chance of selecting strong plants when thinning, and affords food to the fly without losing the crop. The farmer should remember that the fly makes a point of taking its share first, and consequently he must provide for it if he wishes to have any left for himself. *Thirdly*,—sowing while the ground is moist, immediately after the drills are made, and selecting, if possible, the commencement of moist weather. *Fourthly*,—watering the ground when the seed is sprouting, with diluted urine, soap suds, or guano and water, or the drainings of a manure pile. A puncheon with a hole to

let the water run out, placed in a cart with a tight bottom, and a narrow slit or a row of notches under the the tail-board to spread the water, makes a good watering machine; and in dry weather the benefits in promoting growth and driving off the fly will well repay the cost. *Fifthly*,—sprinking lime, wood-ashes, soot, or guano over the young plants, or on the drills when the plants are appearing.

"By adopting these methods, or such of them as may be practicable, a crop may always be secured; and if any vacancies occur, they can be sown with white turnips until the beginning of August, or they can be supplied with plants of mangel wurzel, a bed of which is very useful for this purpose, as they will stand transplanting in any weather. Various dressings for the seed have been recommended, but these do little to protect the leaves; and I have known some of the most offensive of them—as for instance, codfish oil and sulphur—to fail entirely in driving off the insects. It may also be observed, for the encouragement of those who wish to extend their turnip culture, that *large fields* usually suffer less than *small patches*, for a very obvious reason.

"The worm, or caterpillar, has been found a difficult enemy to deal with, as it sometimes attacks the turnip (chiefly the white and Aberdeen varieties) in immense numbers, and devours them very rapidly. In England, flocks of young ducks turned into the fields have been found to destroy the grubs; and it is likely that watering with soap-suds, ley, lime water, &c., would do something toward diminishing their numbers.

"All the root crops above referred to are exhausting in so far as the mineral constituents of the soil are concerned; but they send their roots deeply into the subsoil and feed on it; their tops may be left to enrich the soil; they afford material for making good stable manure when fed to animals; and as they are always put in with a heavy dressing of manure, they leave the land in ordinary circumstances in a better state for grain crops than before.

§ 9. *The Potato.*

The potato contains in its tuber a larger proportion of nutriment than the turnip or carrot, chiefly in the form of starch with a little albumen. It requires the presence in the soil of potash and lime in considerable quantity. Much more than one half of the ash of the stem of the potato consists of these substances, and potash forms nearly one half of the ashes of the root or tuber. Potash is contained in the stable manure usually applied to the potato, and in soils containing lime it thrives well, and is less liable to disease than in others. Some persons suppose that the application of lime and wood ashes causes the potato to be scabbed. This, I believe, is a mistake, but salt and door manure seem to produce this effect. Though the potato will thrive, when otherwise in a healthy state, with raw stable manure in contact with its roots, yet there can be no question that it grows better with rotted manure well mixed through the soil. It is probable that much of the efficacy of sea-weed, which is much used as a manure for potatoes on the sea coast, depends on the soda which it contains supplying the place of potash. The sea manure is thus very useful on the slaty soils; and on the granite soils, which contain much potash, the lime afforded by the sea-weed, is probably of more importance than the soda. Animal manures affording nitrogen, are also very important to the vigorous growth of the potato, as to most other cultivated plants.

As in the present state of the potato, the rot or blight is the most important subject of inquiry, we may devote some time to its consideration; and may begin by stating the leading facts as to its mode of occurrence.

1. The general diffusion and simultaneous occurrence of the disease over extensive regions, is a remarkable fact; and the exceptions arising from the differences of soil and other causes, are also very instructive in suggesting remedial measures. Some of these exceptions will be considered subsequently.

2. The disease has usually attacked the crop at that stage of the growth when the tops are fully formed, and the formation and filling up of the underground tubers are most rapidly proceeding. Yet early potatoes often pass this critical period in safety, while those which are late are attacked; showing that the weather or temperature acts with or against the predisposition at this particular stage of growth, and modifies its influence.

3. The disease has usually first made its appearance in the leaves, and descended from these to the stems or roots. In the leaves and stems, it appears in the form of death and decay of the tissues, very similar to that which results from frost, or the application of any poisonous substance. In the tuber, its progress can be distinctly observed, and is somewhat curious. The tuber consists of a vast number of little cells, or bags, filled with a fluid containing vegetable albumen and other substances in solution, and having small grains of starch floating in it. There are usually several of these starch grains in each cell. Through this cellular tissue pass bundles of vessels or tubes communicating with the eyes or buds on the surface of the potato. The disease usually commences at the surface, immediately under the skin, and usually near the eyes, and penetrates inward along the bundles of vessels. Under the microscope it is seen to be accompanied by the growth of a minute parasitic fungus, analogous to that which causes mildew in wheat, though it has not been certainly ascertained whether this fungus originates the disease, or whether its growth is merely a consequence of the change of the tissues. It is perhaps most probable that the development of the fungus is favoured by the disease previously commenced, and it seems certain that in some cases the disease exists without the fungus. From these it spreads to the walls of the cells, and the fluid they contain becomes decomposed and blackened; and after all the rest has been reduced to a brown putrescent mass, the starch grains still remain entire. It has been observed in some instances, that in proceeding from the stem to the roots, the disease appeared first in the tubers nearest to the stem. The best general view that can be given of such a disease is, that it

is a mortification of the tissues of the plant, proceeding from something which has diminished its vital energies, in such a manner as to allow those changes to go on which ordinarily would take place only after the death of the plant.

As to causes, two important truths, deducible from the facts already stated, at once meet us:

1. A disease so general and widely spread, probably primarily depends on some great, and generally operating, predisposing cause.

2. Notwithstanding this, it is locally induced or prevented by the action of a great number of secondary causes, which favor or arrest its development, and which yet cannot be considered as the primary causes of its appearance. Let us inquire first, into

The inducing or secondary causes of the disease, and remedies or palliatives founded on their study.

Most of these causes it will be necessary merely to name, as the greater number of practical men are well acquainted with them. The principal are wet and undrained soils, wet seasons, wet weather after warm and dry weather when the tops are fully grown, chilly nights succeeding hot days, rank manure in contact with the roots, want of attention to keeping the crop well tilled and free from weeds, run-out seed long cultivated on the same farm. These and similar causes have evidently had an important influence in locally developing the disease, but *none of them can be its general cause*, since the disease often appears where all are absent, and these causes were quite as general as now, in former times, without producing any such consequence as the potato blight. Some valuable hints, however, as to the best palliatives or temporary remedies for the disease, can be derived from these causes, in connection with the experience of farmers. Of these, the following are very important *temporary remedies or palliatives.*

1. *Early planting*, and planting early sorts; because this gives greater probability of avoiding the effects of autumnal chills and rains. This remedy has been found very effectual in Nova Scotia.

2. *Change of seed*, especially from poor and cold localities, to richer and milder situations. The Scottish low country farmers have obtained excellent results by importing seed potatoes from the bleak and poor highland districts.

3. *Selecting* those *varieties* which have proved *least liable* to the disease; and these will generally be found to be such as have been recently introduced, or lately procured from the seed.

4. *Planting in dry soils*, and underdraining more moist soils, if necessary to plant in them. The dry, sandy uplands of some districts have almost entirely escaped the disease, when the crop has been put in early.

5. Applying *well-rotted manure*, and plowing it in, instead of putting it with the seed in the drills. *Guano* and composts made with *liquid manure*, have proved themselves better than stable manure. This and the two last remedial agents act by giving the plants a greater degree of healthy, general vigor, than they could derive from run-out seed, in wet soil, or in contact with rank manure.

6. Planting in *new soil* and the use of *mineral manures*. It is generally observed, that the potato has been most healthy when planted in new, virgin soil, before the unskilful agriculturist has extracted from it the stores of alkaline and other mineral manures remaining in it from the ashes of the forest. The composition of the ash of the potato at once explains the reason of this, as the following table, taken from Johnston, will show:

Ashes in 10,000 lbs. of the roots and stems of the potato.

	ROOTS.	TOPS.
Potash,........................	40.28	81.9
Soda,...........................	23.34	0.9
Lime,...........................	3.31	129.7
Magnesia,......................	3.24	17.0
Alumina,.......................	0.50	0.4
Oxide of iron,..................	0.32	0.2
Silica,..........................	0.84	49.4
Sulphuric acid,.................	5.40	4.2
Phosphoric acid,...............	4.01	19.7
Chlorine,.......................	1.60	5.0
	82.83	308.4

Here we have very large proportions of lime and potash; the latter forming nearly 50 per cent. of the ashes of the roots. Now these substances, potash especially, are plentifully supplied to the soil by the ashes of the woods, and are usually deficient in exhausted lands. Hence, if we apply to run-out, or long cultivated soil, lime, wood-ashes, gypsum, (sulphate of lime,) common salt, (chloride of sodium,) bone dust, (phosphate of lime,) we supply it with some or all of the more important substances in the above table, and thus assimilate it to the virgin soil in which experience proves the potato to thrive best. I have found, by experience, that healthy potatoes (though not a large crop) could be obtained by planting with no other manure than a pint of unleached wood-ashes in each hill, in seasons when potatoes planted with ordinary manure were blighted.

For the same reasons it is, of course, unwise to raise successive crops of potatoes on the same soil. Whenever, on old land, a proper rotation of crops is not attended to, there is much greater likelihood of failure.

7. Storing in dry cellars is of the first importance, when the crop is infected. I have found that potatoes in which brown spots of disease were already formed, had the progress of the change arrested by being kept dry; and that the diseased spots dried up and lost their putrescent character.

8. Where there is no hope of otherwise saving a crop, the rotting potatoes may be grated or ground up, and the farina and starch saved. With a little extra washing, it will be nearly as good in quality, though usually less in quantity, than that from sound potatoes. Every farmer should have a grater or grating machine for potatoes, and in autumn should prepare a quantity of farina. It is excellent for children's food, puddings, to mix with flour for bread, &c.; and it will keep for several years.

All the above, and probably other expedients, have been approved by experience, as useful palliatives. In short, anything that tends to place the plant in a natural and

healthy condition, appears to give it a much greater power of resisting the cause of disease, whatever that may be.*

None of these secondary or partial remedies, however, can be expected to eradicate the disease. They may temporarily prevent it; or, when present, mitigate its violence, or diminish the loss resulting from it. But I shall presently show, that we have no reason to suppose that any, or all of them, can effect a perfect cure.

We proceed then, in the next place, to inquire into the

Primary or predisposing cause of the disease, and its remedies.

Almost every fact that can be collected, seems to indicate that there must be some general cause of this nature, which began to operate only in modern times; and which has, during the last few years, been almost universally active, but modified by the influences of the secondary causes above referred to.

The ordinary popular resource in seeking for the origin of wide-spread epidemics, is to refer them to the atmosphere. "It is in the air," appears often to be thought a satisfactory explanation. If we ask for proof, none can be obtained either from chemistry or meteorology. If atmospheric, then the cause of the evil is likely at once to be beyond our cognizance and control; besides, we are at a loss, on this hypothesis, to account for the apparently almost entire limitation of the disease to one cultivated plant.

On the contrary, every point in the nature of the disease, and the means hitherto found useful in counteracting it, indicate that the defect is in the plant itself; that from some cause its vital force has been weakened, so that putrefactive processes lay hold on the substances which, in a healthy state, it could retain unchanged; and that these putrefactive changes can be arrested only when the cir-

* To this I may add that when the disease is observed in the stalks, the potatoes should be dug at once. If they must be left in the ground, the stalks should be pulled out.

cumstances are in all respects healthy; while unfavorable circumstances, which in former years produced no effect, are now speedily fatal. The occurrence in the diseased potato or on its surface, of fungi, plant-lice, or other enemies, does not disprove these views, as these are always ready to attack tissues previously unhealthy.

Is there then, anything in the past history or present condition of the plant, likely to produce such an effect. I have long thought that there is such a cause, and shall now proceed to explain it, in connection with the only means of counteraction which have suggested themselves.

Of all our crops, the potato alone has been continuously propagated by natural or artificial division of the plant. The tuber of the potato is a sort of underground stem, with eyes or buds intended to produce young shoots in the year following the formation of the tuber, and with a store of starch, albumen, &c., to nourish these young shoots in the early stages of their growth. These tubers, then, in the natural state of the plant, must serve to continue its existence from year to year, and to extend the individual plant into a group or bed of greater or less extent. But this process is not intended to be perpetual. The longest-lived forest tree must eventually die, and so must the group or stool of the potato, which, originally founded by a single seed from a ball, is only one plant increased in extent by a spontaneous division of its roots into detached tubers. It gradually exhausts the neighboring soil, until its own vital energy diminishes, and at length it will die out; and if a new plant occupy its place, it must be a seedling produced from the balls which have fallen on the spot.

If then, since the potato was introduced into Europe about 250 years ago, we have been continuing its cultivation solely by division or separation of the tubers, we have been perpetuating the life of one individual plant; and we must now have potatoes that are the descendants of those imported by Raleigh, not by natural generation through the seed, but by indefinite division of the plant; a sort of infinitesimal fractions by a perpetual division of that now extremely aged individual potato. Have we a right to expect that such

plants should be healthy? We may not know the minute changes which bring about the debility of age, but we know that such debility does overtake plants as well as animals. Fine varieties of carnation, propagated by cuttings or layers, in a few years degenerate, and must be abandoned by the florist. The same happens to other florists' flowers, though in some more slowly. Grafting and budding fruit trees is but continuing the lives of individuals, and despite the vigor of the new stock, grafts from very aged trees of old varieties, show the debility of the parent. Hence, most of the finest fruits of a century or two ago have degenerated and become less worthy of cultivation, and have been replaced by new varieties from the seed. This seems to be one of the great laws of vegetable life; and accordingly, even those plants which, like the potato, have been furnished with tubers to provide for the continuance of individual life, have also been provided with seeds to produce new individuals, and thus permanently continue the species.

Taking this view of the matter, we should rather wonder that the potato has lasted so long, than that it now fails. We can, in truth, account for its long duration only by taking into consideration the variety of soils and climates in which it has been cultivated, the frequent changes of seed, and the occasional raising of new varieties from the ball.

If, however, this cause has had any real influence on the plant, why has it not merely run out or died of old age, instead of contracting a malignant and fatal disease? In answer to this I may remark, that the disease in question is, in fact, merely the death and consequent putrefaction of parts of the tissues of the plant. Further, the analogy of other vegetables leads us to believe that plants do not always simply die out under the influences of degeneracy or old age. The worn-out carnation loses the size and brilliancy of its flowers; the old varieties of fruit trees lose their vigor of growth, degenerate in their fruit, and become very liable to the attacks of parasitic fungi and animals; the ancient forest, its trees decaying at the heart, and overgrown externally with lichens, mosses, fungi, and excrescences, usually

perishes by tempests or fires, before it undergoes the slow process of natural death. So with the potato. Under high cultivation, its starchy and albuminous parts, those which are valuable for human food, have been increased, while, by constant reproduction from the roots, the vitality of the living buds has been diminishing. The potato, at one time the most certain and hardy of crops, has gradually become tender. The "curl" and "dry rot" began many years ago to cut off the young shoots and the planted tubers, apparently because there was not sufficient vegetative life to enable the living bud to control and use the abundant nutriment for it in the cells of the tuber. This difficulty was overcome in part, by changes of seed, planting the whole tubers, and other expedients; and the life of the plant was protracted a little longer, as might have been expected, to be attacked only by some worse disease. And now we have to contend with a mortification of the tissues, not in the infant stage, but in the period of the plant's fullest vigor and strength.

It may be objected, that even renewal from the ball has not been effectual, the seedling varieties having suffered as well as others. It must be observed, however, that seedling varieties have generally resisted the disease longer than others, and that there seems good reason to believe that the disease, like most others that originate, whether in plants or animals, from long exposure to debilitating influences, is more or less contagious. It is quite probable also, that the seed of plants which have already contracted the disease, may be itself not quite free from hereditary taint. Renewal from the seed cannot, therefore, be assumed to have been fairly tried, unless the seedlings have been, at all stages, completely separated from the old varieties, and unless they have been derived from healthy plants, or are separated, by a sufficient number of removes, from their unhealthy progenitors.

I come now to the method which the above views would lead us to consider the only certain one, with a view to the final extirpation of the disease, and it is one requiring the means at the command of the government of a state, or

some public body or institution, devoted to agricultural improvement.

It is to cultivate the potato from the ball, for several generations continuously, until the hereditary taint is removed, and then to distribute the healthy tubers to such agriculturists as will pledge themselves to abandon entirely the culture of the present exhausted and diseased varieties.

To succeed in the experiment, it should be conducted on a well-managed model farm, or horticultural garden, from which the culture of the old varieties should be entirely excluded, and seed should be obtained from the balls of the most healthy potatoes.

The ground should be light and dry, and manured with a mixture of old compost, lime, gypsum, and wood ashes.

The seedlings should be carefully tended and kept very clean from weeds, and any plant, in which the first signs of blight appear, should be at once destroyed.

A part of the seedlings should be carefully covered, and allowed to remain in the ground all winter. The remainder should be carefully packed in dry sand, in a cool cellar, keeping the various sorts separate.

In the second year, the same precautions should be used as to the culture of the best varieties obtained in the first year, and some of the plants should have the soil washed away from their roots, and the young tubers picked off, in order to ensure the production of the balls. After picking off the tubers, the plants should be carefully earthed up again.

The seed from the balls of the second year should be sown in the third year, and the whole process repeated as before. The tubers obtained from the first sowing should not be distributed as seed potatoes; but those from the second sowing might, if no disease had appeared in the course of the experiments. If disease had appeared, the process should again be repeated.

The best varieties obtained from the produce of the third or second sowings, should be planted out, to furnish seed tubers, with the same precautions as to manure, &c.

The sound tubers should be given or sold to farmers, who

would pledge themselves to cultivate no other varieties, so as to secure them against contagion.

A national nursery for new varieties of potatoes, on the above plan, should be kept up in every agricultural country, so as continually to supply new and sound varieties. Independently of the prospect of gradually restoring the potato culture, the improvement of the sorts cultivated would amply repay the expense. In the same farm, or garden, experiments might be tried in the culture of wild varieties, obtained from the native country of the potato.

The above suggestions are submitted as probably far superior to any founded on the belief of any one method or substance being effectual as a cure. Such partial remedies, though they may be temporarily successful in particular soils or seasons, never can effect the general or permanent removal of the evil.*

§10. *Clover and Grasses.*

In a country where the winter is long and severe, these must always be important crops; though, as already hinted, when treating of the climate, it is certain that the extended culture of root crops, to be fed to cattle and horses in winter, would very much lessen the present difficulties in this respect. I have already quoted the opinion of Professor Johnston on this subject, and now give an additional extract, on the former and present state of Scotland:

"The same state of things as now exists in New Brunswick, existed in Scotland, in connection with this branch of husbandry, about a hundred years ago. Cattle were killed at the end of summer, and salted for winter use, because the stock of hay at the farmer's command was not sufficient to keep them through the winter months. The beef these cattle gave was so poor that it took the salt badly,

* The above explanation of the Potato rot was first published by the author in the Report of the Agricultural Societies of Massachussetts for 1851. It has since been often reproduced by various writers, and has been to some extent reduced to practice in the production of new varieties of the potato.

was hard and indigestible, and kept badly in the brine. Now, the cattle are not killed in the autumn more than at other seasons. The present modes of husbandry provide winter food for all the stock the farmer finds it convenient to keep. When killed, the beef or mutton is now of excellent quality; large quantities of both are forwarded, all the year through, to the southern markets; and it can be cured for the naval service, or for any other use."

It appears to me that, in the present state of our husbandry, the most important points to be considered in reference to hay crops, are, in the first place, the injurious practice of cutting hay from the same ground for a great number of years in succession; and secondly, the best modes of promoting and ensuring the growth of clover. To these subjects, therefore, I shall devote the remainder of my remarks under this head.

The skilful farmer should never forget that run-out hay land is in every respect unprofitable. It costs almost as much per acre for fencing, mowing, and raking, as better ground, and yields little, and this of very inferior quality, possessing little nutritive power. In dry seasons, also, it cannot be depended on. Hence one acre capable in a good season of yielding three tons, or two tons in a poor season, is far more valuable than six or seven that in a good season may yield, perhaps, one ton per acre, and in a poor season fail altogether. Hay land should be sown out in good heart, and then not more than two crops should be taken, at least without some fertilizing top-dressing; and even with top-dressing, not more than three or four. After this, if it cannot be broken up, it should be left for pasture. Circumstances may render necessary partial deviations from this rule; but the principle should be considered as settled, that every deviation will entail loss in the end. Every farmer, on ploughed land, can at least apply this principle to a part of his land—and the larger that part the better. In connection with this it must be remembered, that good summer pasturage, independent of more direct benefits, does much to aid good winter keeping. Hay culture, without impoverishing the land, is, after all, not so difficult as may

be imagined; for the liquid and solid manure of the animals that consume the hay, contains nearly all that the hay took from the soil; and if saved and restored, no impoverishment results. On the other hand, the grand secret of hopelessly and rapidly impoverishing the farm and the farmer, is to crop the land in hay till it will bear no more, and then let the manure go to waste, or sell off the hay. Johnston in his Report on New Brunswick, gives the following example of a prevalent error in this respect: "I visited the farm of a most intelligent gentleman, one of the best farmers in his neighborhood, and, I believe, most desirous to improve; who informed me, that after one dressing with mussel mud, from the sea bank not far from his farm, he had taken one crop of potatoes or turnips, one of wheat, and eight successive crops of hay; and he seemed to think the land had used him ill in not having given him more. For the first four crops, from such an application, a British rent-paying farmer would have been thankful and content; and in taking these, he would have been thought rather hard upon his land."

The timothy grass (herd's grass) usually cultivated in this country, is one of the best of grasses, in every respect. It is, however, often treated with injustice, by being allowed to remain too long before cutting. Where there is a large crop to be cut, and few hands, mowing should, if possible, be commenced *before*, rather than after the flowering of the head,—which is the time when the grass contains the largest quantity of nutritive matter. It is true, however, that few grasses will bear late cutting better than herd's grass. Even when left to ripen its seeds, it is worth more as food than many of the light grasses of worn-out lands. The substances which this grass requires to be present in the soil, are very much the same with those needed for grain crops. Its favorite ground is a moist and deep soil.

Clover is a most valuable adjunct to herd's grass, especially in the lighter soils; but the conditions necessary for its successful culture are as yet very imperfectly known in this country. The ashes of clover contain large quantities of potash, lime, and gypsum. These substances must

therefore be present in the soil. Clover loves a calcareous soil and hence it is observable that in those soils which, from the vicinity of beds of lime and gypsum, are naturally rich in calcareous matter, clover thrives without any trouble. I place first therefore, among the requisites for the successful culture of this crop, the presence of lime and gypsum in the soil. If not naturally present, they must be supplied artificially. The next requisite is a deep and dry soil. Clover sends its roots deeply into the ground, and will not thrive in shallow wet soil. To fit it for clover, such soil should be drained and subsoiled. Thirdly, the leaves of the clover must not be destroyed by the scythe or by cattle, in the autumn of the year in which it is sown. These leaves ought to be employed till the frost kills them, in preparing nourishment for the growth and strengthening of the root; and if cut early with the grain, the plant is so enfeebled that it has little chance of standing in winter. In reaping, the wheat straw should be cut so high that the scythe or sickle shall not touch the clover leaves. This high stubble will also shelter the clover in winter. Of course, no cattle or sheep should be allowed to enter the stubble fields in autumn. Fourthly, the ground should be rolled in spring, to press in the clover roots. Fifthly, after clover has been sown several times, in the ordinary course of successive rotations, the land becomes "clover-sick," as it is termed, and the crops fall off. In Britain, pasturing for several years has been found to cure this; and manuring with wood ashes, lime composts, and urine, have also been found beneficial.

Neglect of these facts is the principal cause of the two great evils complained of in this country in respect to clover, viz: the winter-killing of the roots, and the too early ripening and death of the top in summer. These losses are often attributed to particular varieties of seed; but they depend far more on the nature of the soil and treatment,—though of course, some unfavorable seasons occur, in which no management is altogether effectual; and as the natural life of red clover does not extend beyond two or three years, it cannot be expected to remain permanently

in the land. Shallow undrained poor soils, which do not allow the roots to become large and strong in the first year; destruction of the leaves of the first year in autumn; deficiency of lime and alkalies; and neglect of rolling,—are the principal causes of winter-killing; and the same causes, with the addition, in old farms, of clover-sickness, cause the crop to ripen prematurely.

Jackson, in his Agriculture and Dairy Husbandry, states, that clover may be very successfully sown with flax. This fact may be useful to some farmers.

The expense of clover seed tends to prevent the poorer farmers from using it more freely, and hence the land has generally too little seed to give a good crop in the first season. There seems no reason to prevent the seed from being more extensively cultivated in this country. The directions usually given for this are, to allow cattle to eat down the leaves in early spring, or to cut the leaves very early, and then to protect the second growth, and allow it to ripen its seed. The process for cleaning the seed may be seen in many agricultural books. This is a subject deserving the attention of Agricultural Societies, which might usefully give premiums for the best and largest samples.

§11. *Flax, Hemp, Broom Corn, &c.*

The culture of *Flax* has of late been much recommended, more especially since the recent scarcity of vegetable fibres for textile manufactures commenced, and there can be no doubt that it might be made the means of securing a profitable article of export, as well as of establishing domestic manufactures. On this subject, we cannot here enter into details which belong to the mechanical part of agriculture, but may notice a few points connected with the composition and habits of the plant. Flax requires very frequent changes of seed. Sowing seed raised in another country, gives a remarkable stimulus to its productiveness. In Britain, American and Riga seeds are imported and sown, and flax growers always prefer this foreign seed, or that

which is but one remove from it, to their own. In this country, where farmers sow seed raised on their farms year after year, short crops must necessarily be the result. Flax prefers well-elaborated manure, and must, of course, have clean land. Its proper place in a rotation is, therefore, after a well-tilled green crop. A dressing of lime, or wood ashes, sown with the seed, or after it is up, will be found very advantageous. I have already stated, that grass and clover may be sown with flax ; and I may add, that the Belgian farmers are of opinion that the young grass and clover are not injurious, but, on the contrary, beneficial to the flax.

Flax has usually been considered an exhausting crop ; but the success of clover after it, shews that this is not strictly true. The fibre and seed of flax probably take less from the soil than the grain of a wheat crop. The greater part of the inorganic matter taken from the soil is contained in the refuse of the dressing; and if this be composted or otherwise saved, and restored to the soil, no exhaustion will result. If clover succeed the flax, and be ploughed down after the second crop, its roots will replace most of the organic matter abstracted by the flax. Flax extracts much from the subsoil, and is partial to a calcareous soil, and much benefitted by lime. When yield of seed is an object, an abundance of organic manure in the soil is important; but for flax of fine quality, if the inorganic matter required is present, rank manures are objectionable.

The precise requirements of flax, as to inorganic food, are shown by the following analysis by Johnston of the ashes of the flax fibre and of the refuse or *pob*.

	Flax.	*Pob.*
Alkaline salts, chiefly common salt, and sulphate of Potash	8.93	9.58
Phosphates, chiefly of Lime and Magnesia.	17.89	14.12
Carbonate of Lime	45.56	51.43
Carbonate of Magnesia	6.38	9.24
Insoluble silicious matter	21.24	15.63
	100.	100.

This table shows how important it is to restore as manure to the soil the pob or dressings of the flax, and also that to restore the fertility of land exhausted by this crop, lime, bone-earth, and wood ashes would be suitable manures. Guano would be very valuable in this respect. It has also been ascertained by Sir R. Kane, that the water in which flax has been steeped, contains much nitrogenous matter, and also many saline substances, in solution, and is most valuable as a liquid manure.

Hemp is also worthy of the attention of farmers, and is largely cultivated in climates similar to ours. It requires good soil, and is said to clear the ground of weeds. Grain and grasses thrive well after it, which would indicate that it is not a very exhausting crop. The plants are male and female, the latter of course alone producing seed; but the former, which is smaller and more delicate, producing the best lint. The seed of both sexes must be sown together, and both may be dressed together, but it is advisable to have a separate patch, from which most of the male plants have been thinned out, for seed. The crop, when ripe, which is known by the disappearance of the farina or bloom of the male plant, and the partial withering of the leaves, is pulled like flax, or cut near the ground, and its subsequent treatment resembles that of flax. After being broken on a hand-brake, somewhat stronger and larger than that used for flax, it may be sold to the manufacturers without further preparation. An acre yields from 6 to 10 cwt. of prepared hemp. The breaking of hemp furnishes good employment for idle hands in winter. It would probably thrive well on our dyked marshes and intervales, and on the deeper loamy uplands. A very particular account of the mode of preparation, by the Hon. H. Clay, is given in Fessenden's American Farmer.

Broom Corn is a crop of profitable culture wherever the climate is sufficiently warm, and in many parts of British America this is the case. The stalks or their upper parts sell profitably for broom-making. The seeds are said to be equal in value to a crop of oats. It requires rich manure, and cleaning with the hoe; and its general culture resembles

that of Indian corn. It is, no doubt, an exhausting crop; as it grows to a great height, and a considerable part of its strong woody stalk is sold off the farm. Full directions for its culture will be found in the American Agricultural books.

The *Chinese sugar cane* is a plant similar to Broom Corn in its culture, and is useful for feeding cattle, and the production of syrup. It grows well on rich loamy soils in Canada, though its seed does not ordinarily ripen, at least in Eastern Canada. It sometimes attains the height of nine feet, and affords much highly saccharine syrup as well as nutritious food for cattle.

§12. *Orchard Culture.*

The culture of fruit trees is largely and skilfully practised in some parts of the country; but in others it is little attended to. There can be no question, that wherever soil and circumstances are favorable, it well deserves attention, on account of its market value, and its contribution to family comfort and to the beauty of the farm. I shall, under this head, notice a few requisites for a good orchard, and the remedies for the more destructive blights and diseases to which fruit trees are liable.

It is of the first importance to have a suitable soil and exposure. The apple prefers deep loams, or sandy loams; —the red loams of parts of the Lower Provinces, and the deep shingly soils of the inland hills, are especially adapted to it. The pear does well in similar soils. The plum does not object to a stiff clay, and will not grow luxuriantly in some of the lighter soils, in which the apple flourishes. The cherry, on the contrary, prefers a light dry soil. Much can be done, however, by proper drainage and manuring, to render all ordinary soils suitable to these and other fruit trees. A good exposure should be selected; and where there is not natural shelter, belts or rows of trees should be planted on the sides exposed to the cold winds. Cherry trees suit well for this purpose; so do spruces. The butternut tree has also been recommended; and, indeed, any

rapidly-growing tree, suitable to the soil, will serve the purpose. The ground should be well tilled, drained, and manured. It is folly to plant valuable trees in a poor, cold, undrained soil; and it is folly to plant worthless or inferior trees at all, when good sorts can be procured.

Trees should be lifted with care, so as not to injure the roots; as these are all required to nourish the tree. They should be planted with like care,—spreading out the roots in a natural form, and trimming off some of the young shoots from the top. Holes for planting should be made both larger and deeper than is absolutely necessary; and the surface-soil, with compost or rotted manure, should be turned into the bottom of the hole. If the soil be deep and dry, the tree may be set pretty deeply; if cold and shallow, the tree should be nearer the surface. The earth should be carefully pressed around the tree; and a little straw, or a few sods or some seaweed, laid on the surface, to preserve the moisture of the soil. Bones, parings of hides and horns, hair, and similar animal matters, are excellent and permanent manures for young trees. After planting, the ground should be kept clean, and regularly manured with old compost, ashes, ditch cleanings, or animal matters; and on no account must it be allowed to become covered with a tough grass sward, especially in the case of apple trees. Trees are often seen growing in old grass sward, regularly mowed, and seldom or never manured. Such trees must eventually become unproductive and diseased. Trees extract large quantities of matter from the soil, and require plentiful manuring, especially when another crop is being taken from the same soil. Hence it is a good plan to plant orchards very open, and to cultivate and manure the ground in regular rotation; taking care not to damage the roots unnecessarily, and not to leave the land long in grass. The apple is much benefitted by frequent stirring of the soil;—stone fruits require less of this, and are more apt to be injured by wounds inflicted on their roots.

When it is desirable to plant out trees before the ground is properly prepared, or when it cannot be tended as it

requires, seedlings or slips may be planted out, instead of grafted trees; and such of them as become strong and vigorous, may afterwards be grafted with good sorts. In like manner, farmers who have young trees of wild or inferior kinds, may have them headed down and grafted upon;—if skilfully done, the grafts soon come into bearing. In planting, abundance of space should be left for air and light. When early produce is desired, the trees may be planted at half the proper distance apart, and each alternate tree may be forced into early bearing, by *root* pruning and shortening-in the branches. These trees may afterwards be cut out, when they interfere with the others.

Pruning is a most important part of orchard management. Trees should be kept open, and trained symmetrically, so as not to permit the branches to interfere with each other, and to present the greatest possible surface to air and light. There are various modes of pruning, but all depend on this principle; and wall, espalier, round, oval, or conical training may be preferred, just as one or other may appear, in the circumstances or situation, to be more or less adapted to promote access of air and light. The perfection of pruning, is to study the growth of the tree, and cut out as early as possible every twig that interferes with the intended plan, or with the symmetry of the whole. When it becomes necessary to cut out large branches, more or less permanent injury to the tree is unavoidable. The cutting off a large branch is somewhat analogous to the amputation of a limb in an animal, and more or less deranges the circulation of the whole system. Large limbs should be pruned in summer; small twigs may be freely cut in spring. Experience has shewn, that the dangers of spring pruning, in the case of considerable limbs, are much greater in stone fruits than in apples and pears.

On the subjects of grafting and selecting of sorts of trees, I may refer every beginner in orchard culture to Cole's American Fruit Book, a cheap and excellent little work.

The *diseases* and *enemies* of fruit trees should be carefully studied, both in books and in nature, by every fruit

cultivator. They are very numerous and troublesome, though often sufficiently interesting and curious. In the following remarks, I shall give principally the results of my own observations in this country; and it is, of course, possible that I may have overlooked some pests of the orchard known to other persons.

1. The *Scale Insect* or *Bark Louse* (*Coccus*) attacks the apple tree, and, though not rapidly destructive, much impairs the vigor and productiveness of the tree. It is a small whitish creature, residing under a greyish scale attached to the bark, and is, in its adult state, quite incapable of locomotion. It appears to subsist by sucking the juices of the inner bark, to which, when very numerous, they give an unhealthy brown color. In autumn, the adult deposits under the scale a number of whitish eggs, and dies. In spring, the young are hatched on the approach of warm weather, usually in May, and make their way to the younger twigs and branches, where they fix themselves, and acquire a scaly coat, like their parents. To destroy these insects, the branches should be washed with lime in early spring. This prevents the young from extricating themselves from the old scale, or from attaching themselves; and they consequently perish. At the same time, the tree should be well manured, to give a vigorous growth, and the loose outer bark should be scraped from the trunk before the lime is applied. In this way, a cure can be easily effected in the case of small trees.

2. The *Tent Caterpillar*, or web-weaving caterpillar, attacks all kinds of fruit trees. It is the larva of a moth, *Clisiocampa*, which, in autumn, deposits its eggs in a ring surrounding a branch. In autumn, winter, and early spring, these deposits of eggs should be searched for and removed. The trees should also be carefully examined in spring and summer, and every little cobweb curtain that is observed, should be cut off, and its inhabitants crushed; or if it be too large to permit this to be done without injury to the tree, the web and insects may be brushed off with a mop, or broom, dipped in a strong solution of soft soap.

3. The *Tussock Caterpillar* is a creature of gay colors, and ornamented with long tufts of black hair. It is the most beautiful of our caterpillars; and, singularly enough, in its perfect state, it is one of the plainest of grey moths. It belongs to the genus *Orgyia*. The female is an unsightly wingless creature, remaining motionless on the spot where she emerges from the hairy cocoon in which the full-grown caterpillar envelopes itself, when about to enter on its torpid or pupa state. Attached to this cocoon, she deposits a mass of eggs, enveloped in a hard spongy whitish varnish, intended to protect them from the rains and storms of winter. Owing to this circumstance, the eggs are easily observed; and when seen in autumn or winter, attached to limbs of trees, fences, or buildings, they should be brushed down and destroyed. When the caterpillars are hatched, if abundant, they soon strip a tree of its leaves; and means should at once be resorted to for their destruction. The best method is to drench the tree with a solution of whale oil soap, or soft soap, common soap-suds, or weak potash ley. This may be sprinkled with a mop of rags, or, better, with a garden syringe. Small trees may be sufficiently sprinkled with a garden watering pan. Soap, applied in this way, is a useful remedy for the attacks of all kinds of caterpillars. Much injury may also be prevented by smearing the lower part of the trunks of trees with tar in spring; as some kinds of caterpillars, and the canker-worm among the rest, are occasionally hatched on fences, outhouses, &c., and make their way into the trees by climbing the trunks. American books say, that the canker-worms may be shaken down from the tree, and destroyed on the ground. I have not found this to be the case with the species common here, as it clings very tenaciously to the limbs. Some other kinds of caterpillars may, however, be shaken down.

4. The *Apple Worm*, the larva of a species of moth, *Carpocapsa pomonella*, burrows in the apple, devouring a part of it, and causing it to fall prematurely. On arriving at maturity, the grub creeps into a crevice or sheltered place, and spins a neat whitish cocoon, within which it

remains till it comes forth in the perfect state. The best remedy is to pick up and destroy all the fallen apples; hogs are sometimes allowed to devour them. If this be attended to, the numbers of the apple-worm will speedily be diminished.

5. The *Black Wart* attacks plum trees, and sometimes cherry trees; and, if allowed to proceed unchecked, is a fatal disease. It seems to be a fungus, analogous to the "spunk" and other dry fungi often found on forest trees; and it probably diffuses itself by spores, or dust-like seeds, carried by the wind. Every affected branch should be cut off so soon as the disease is observed, and should be burned, or carried to a distance from the orchard. In the case of plum trees, salt, or pickle—which, in moderate quantity, is by no means injurious to these trees—should be scattered around them; and though it may not wholly prevent the black wart, it will much mitigate its destructive effects.

6. The *Plum Weevil*, or *Curculio*, is a small beetle, (*Rhynchænus nenuphar*) which deposits its eggs in the young plum. The grubs prey on the fruit, and cause it to fall prematurely; after which they burrow in the ground, and come forth in the next season as perfect insects, which creep and fly into the tree. The remedies which have been found useful, are:—1. Manuring with salt, which is said to render the fruit distasteful to the grub. 2. Picking up and destroying the fallen fruit. 3. Putting a girdle of cotton wool or tar around the trunk, which arrests the beetles in their ascent. 4. Treading the ground hard around the tree, which tends to prevent the grubs from burrowing. Plum trees in light soils, are more liable to be attacked by these insects than those in stiff soils.

7. *Plant-lice*, and *Mites*. These creatures are often injurious to fruit trees, especially to the plum, and sometimes kill them. A little red mite, or red "spider," as it is sometimes called, and two or three species of green and black plant-lice (*aphis*) are especially troublesome. The best mode of destroying these creatures is, to drench the tree with soap-suds, or ley, or to smoke it with tobacco,

—The larvæ of the common little red *lady-bugs*, (*Coccinella*) are great devourers of aphides. They are hideous-looking large-headed grey caterpillars, which, when disturbed, erect themselves on their tails with a jerk. Their good offices in destroying plant-lice, entitle them to rank as true "farmers' friends."

8. The *Cherry Slug* is a small slimy dark-colored caterpillar, the larva of a little blackish fly (*Selandria Cerasi*). They often appear in cherry trees in considerable numbers, without doing much injury; but when very numerous, they should be destroyed, by dusting the leaves with wood ashes or lime.

9. Many other creatures might be added to this list of destroyers. The Apple-tree Borer (*Saperda candida*), and the apple *Buprestis*, or snapping beetle, devour the wood of the trunk of the apple tree; and among the devourers of the leaves may be reckoned different species of palmer worms or weaver moths, the caterpillars of insects of the genus *Chætochilus*, as well as many other caterpillars; but, with the exception perhaps of the Borer, none of these attain to the destructiveness of those already mentioned, in British America. Couper recommends as the best mode of guarding young trees against the Borer, to surround their trunks with a band of grafting clay, two inches thick, from the ground to a height of two feet.*

10. It may be remarked, in general, with respect to all the enemies of fruit trees, that the orchardist should encourage all the insectivorous birds,—robins, swallows, fly-catchers, titmice, wrens, warblers, &c.,—to frequent his orchard. Some of these birds commit occasional depredations; but, in the main, they are admirable assistants in the destruction of noxious insects. They should be protected from injury; and the cultivator would do well to imitate them, in their activity, vigilance, and prying search for every living thing that shelters itself on bark, leaf, or limb.

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* Canadian Naturalist, Vol. VIII.

CHAPTER XIV.

SUGGESTIONS AS TO PRACTICAL APPLICATIONS.

The young agriculturist has presented to him by the study of this subject a number of topics of thought and inquiry, such as the improvement of barren or run-out soils, the most economical use of manures, the proper succession of crops on a given soil, and the uses of crops in feeding. In each of these he may meet with difficulties as to the application of the principles and facts stated, and with objections on the part of practical men. A few examples of these may be usefully given by way of conclusion.

One of the difficulties is that of obtaining satisfactory information as to the soil on which he has to operate. He can easily ascertain its mechanical quality, and general features, as argillaceous, silicious, and so on; but its intimate chemical constitution may be involved in doubt. If he can have a chemical analysis executed by a reliable practical chemist, this will be one sure means of information. Still in many respects even the most accurate results of the chemist are not sufficient for practical purposes. When a good chemical analysis shows the *absence* or *scarcity* of one or more important ingredients of fertile soils, this is a fixed and valuable fact. It is, however, just in this negative direction that an unskilful analysis is most likely to err. On the other hand, the *presence* of a substance in the soil, does not prove its *availability* for the use of plants, and there are cases where on this account chemical analysis gives a much too favorable result. Supposing a good analysis obtained, the farmer must still satisfy himself whether the substances which it shows are available. If no analysis can be obtained, he must ascertain the whole of the facts required in some other way.

The surest mode of testing the soil practically, is by means of experiments with crops and manures. Let a given surface of soil be divided into portions, and sown or planted with several kinds of crops without manure. This will give an indication, by the yield obtained, as to the fertility of the soil, relatively to these crops; and the known composition and habitudes of these plants will indicate why one thrives better than another. Large straw and leaf in wheat or barley, will indicate the presence of silicates and alkalies; abundant and healthy seeds that of phosphates. Large potato tops indicate the presence of potash; clover is a test for lime and sulphates, and so on.

If the soil has proved itself poor for all or any of the crops tried, it may again be tested with the manures which it may be supposed to want, and the results compared with those of the same crop on an unmanured patch. This may be done on a small scale; using superphosphate of lime, wood ashes, gypsum, peat compost, or other substances in given quantities per acre. The results should be observed for two or three years, as the effects of some of these substances may be more or less permanent.

Such trials, judiciously made on a small scale, with reference to chemical principles, will eventually give information which may be applied to the whole farm. No expensive failures will be made, and the improvements will carry their own evidence with them. The result of such experiments may be further tried by observation of the natural herbage or forest of the ground, and of the results of the culture of different crops or the application of different manures on the farm in the course of its culture. The trials which may be made on neighboring farms having similar soil, are also to be observed in this way. Supposing the experimenter and observer to be a person of sound judgment, and to have mastered the elements of agricultural chemistry, the conclusions reached will assuredly be a safe guide for practice.

It may be useful to state, by way of contrast, some of the errors which proceed from inattention to, or ignorance of, scientific principles.

Liebig, the great German chemist, had maintained the importance of mineral manures to the growth of wheat. In this he was right, but the most silly uses have been made of his statements. Mineral manures have been prepared, containing in due proportion the substances required for the ashes of a crop of wheat, and it has been supposed that this must necessarily be the proper manure to apply for the culture of this plant. But nothing can lead to greater mistakes in practice than this notion. If the land already contains the materials of many crops of wheat in an available state, then the addition of a small dressing of these can scarcely give any appreciable result. If it want one or two of them, then these alone will be of service, the others may be dispensed with. If it is utterly barren, then the quantity of such material which should be applied must be vastly greater than that required for one or two crops. Thus the use of such a manure can be profitable only in certain circumstances, which must be ascertained in the first instance.

To determine the precise value of such mineral manures, Messrs. Lawes and Gilbert, two eminent English agriculturists, undertook a series of experiments extending over ten years. Unfortunately, however, they proceeded without thinking of one of the most important conditions of the experiment. This was that the soil experimented on should be destitute or deficient of the materials added to it. On the contrary they selected a spot which, as the experiments themselves showed, possessed already enough of mineral manure for several crops of wheat. On this account, as might have been expected, small quantities of mineral manures produced scarcely any improvement of the crop. Any school-boy, who had studied the elements of agricultural chemistry, could have told the experimenters this before they began. Yet these costly experiments were made, and the results paraded as conclusive evidence of the worthlessness of mineral manures, when in reality they only proved the incompetence of the experimenters for the work they had undertaken. Many trials made on a small scale fail from a similar cause.

Again: It must be taken into account that a manure of the greatest value on one soil may be quite useless on another. A farmer cultivating a soil deficient in lime, is induced to apply a large dressing of this substance. The results are extraordinary, because previously the crops were stinted of this material, and it was perhaps wanted also to promote necessary changes in the soil. He announces to others the great effects produced; and another farmer cultivating a highly calcareous soil, straightway applies lime, but without any beneficial effect, since the land has already enough of it. He of course condemns lime, and with it the book-farming which has led him to waste his labor and money. An inland farmer uses salt with advantage; and another, living on the sea coast, where the spray, carried by the winds, sufficiently salts the soil, tries it, and finds it worse than useless. Such want of attention to the circumstances of individual cases vitiates a great part of the correspondence of agricultural journals, and renders it valueless, unless commented on by an enlightened editor, or read by persons who understand the reasons of the success or failure in each particular instance.

Farther, a mineral or artificial manure, very useful at first, may in time fail to have any effect, or may even exhaust the soil. Take the instance of gypsum already referred to. When applied to soils deficient in sulphates, it produces magical effects; but if trusted to as the only manure, it ceases to do good, and the land appears poorer than ever. It is then decried as a stimulant, and abandoned in digust. The same result in the case of lime originated the English proverb that it makes rich fathers and poor sons. This must necessarily happen in the case of all partial or special manures. In an article written several years ago, for an agricultural journal, the case was put in the following way: Let us suppose that any cultivated crop requires from the soil equal quantities of three substances, which we may call A, B, and C, and that the soil of a field is capable of supplying in one year 1A, 2B, 3C, the plant, requiring equal quantities, can only avail itself of 1A, 1B, 1C, while 1B and 2C

remain as surplus or go to waste. Let the farmer now apply annually 1A to the field as manure, the plant now takes 2A, 2B, 2C, and the crop may be doubled. But it is evident that the increased crop exhausts B and C more rapidly than the previous small crop. Hence perhaps in a few years the proportions in the soil are reversed, and it can yield only 1B, and 2A, and 2C to the crops. The crop will now fall to its originally small amount, and it is B that must be added to supply this new deficiency; any quantity of A doing no good when applied. This simple consideration explains many results otherwise puzzling, and we may add that the only manures which really contain the whole of the food of plants, are those afforded by the liquid and solid products of the stable, and animal and vegetable substances of similar composition. Other manures are in their nature special and partial, and though their application achieves some of the greatest and most profitable triumphs of scientific agriculture, their misapplication through ignorance of the chemical composition of crops, soils, and manures, does very much to bring the whole scientific theory of agriculture into most undeserved contempt with practical men. It is hard that science should bear the blame of errors which arise only from the want of it; yet this must be the case until farmers and agricultural writers familiarize themselves so far with the principles of chemistry as to be able to understand the meaning of the experiments which they make, and the results at which they arrive.

In conclusion, the young farmer must be cautioned against supposing that this little book contains the whole theory of agriculture. On many important subjects, as for instance the applications of physiology to the feeding and care of animals, it has not entered; and of those to which it has adverted, it has given merely the elements. It may, in a subject advancing so rapidly, and to which the writer cannot give undivided attention, have failed to attach to some facts or principles their true value. The subject is a large one, affording ample scope for all the observation, thought, and reading which the professional farmer can

devote to it. Having mastered the elements as given in the foregoing pages, he should provide himself with good books and journals treating of the subject, and thus go on to make himself so familiar with all its details, that he will be at home in every part of his profession, and able to state a good reason for all that he does.

So doing, the young farmer will be enabled to avoid the misfortunes which arise on the one hand from the apathy and listlessness of ignorance, and on the other from the rash experiments of half knowledge. He will be able to avail himself of all that is new and valuable in improvements introduced abroad. He will cultivate an enlightened regard for the resources and privileges of his country, and will despise the croakings of those who condemn climate and soil when they should condemn themselves. He will regard agriculture as truly a *learned* profession, requiring, for its successful prosecution, enlarged general intelligence and acquaintance with scientific principles. He will regard it also as a profession more intimately connected than any other, with those great natural processes by which God provides out of the earth food for every living thing, and with all that is beautiful and attractive in the face of external nature,—a profession therefore, worthy of thought and study, and leading to love of country and of home, and to the cultivation of those tastes and habits that make home agreeable and happy. Such views will make him disposed rather, by persevering and intelligent industry and care to build up his own prosperity and that of his native land out of the rich resources which it possesses, than to throw himself on the uncertain chances of emigration, or to abandon agriculture for some other calling perhaps less conducive on the whole to his own interests or those of his country.

APPENDIX.

I. APPLICATION OF METEOROLOGY TO AGRICULTURE.

The importance of foresight of the weather to the farmer is often very great; and many observant farmers acquire, by experience, a knowledge of the signs of change applicable to their own locality which is almost unerring. To those who have not this skill the barometer is a very useful instrument. Its fall and rise indicate with great certainty the approach of stormy or fine weather, and may be safely relied on for regulating farm operations. Cheap barometers applicable to farm use may be obtained of the philosophical instrument makers or hardware merchants of most of the large towns.

Some useful guidance in farm work may also be obtained by a study of the results of the observations of meteorologists. A few of these results I shall present in the following tables, as specimens of the information of this kind which has been collected. For the first table I am indebted to Dr. Smallwood, Professor of Meteorology in McGill College.

I. AVERAGE NUMBER OF RAINY DAYS AND HOURS OF RAIN IN EACH MONTH, *from 1st April to 1st December.*

	Rainy. Days.	Durat. of Rain. h. m.
April	8.2	46.15
May	11.0	48.28
June	12.3	49.19
July	10.3	32.55
August	11.0	37.56
September	11.5	57.39
October	12.1	62.00
November	8.2	47.08

The above table represents the mean of twenty years. It indicates the amount of rainy weather that may be *expected* in each month. It applies specially to the vicinity of Montreal.

For comparison, I add a similar table prepared by Henry Poole, Esq., for Pictou, Nova Scotia, which is nearly in the same latitude with Montreal, but eleven degrees farther east.

II. RAINY DAYS AT ALBION MINES, PICTOU—MEAN OF TEN YEARS.

	Nights.	Days.	Quant. Inch.
December	5.5	12	4.8198
January	5	11	3.3814
February	4	9	3.2673
March	4	10	4.3963
April	4.3	8.3	2.6500
Total for five non-working months	22.8	50.3	18-5148
	Nights.	Days.	Quantity.
May	4	9.5	2.8976
June	5	9	2.1338
July	5	10	3.0052
August	5	9	4.5006
September	4	8	3.1520
October	6	9	5.6016
November	4.5	11	4.3984
Total for seven working months	33.5	115.8	47.2040

The following table from the records of the Magnetic Observatory, Toronto, I owe to the kindness of Professor Kingston, Director of the Observatory. It applies to a large district of Upper Canada.

III. RAINY DAYS AND AMOUNT OF RAIN AT TORONTO.

Month.	Average No. of Rainy Days. 1840—1862.	Average duration in Hours. 1854—1862.	Average depth in Inches. 1840—1862.
March	6.0	36.59	1.548
April	9.5	44.14	2.398
May	11.3	57.22	3.241
June	11.9	40.23	3.100
July	10.0	34.14	3.490
August	10.2	35.52	2.951
September	11.2	40.31	3.973
October	11.7	47.42	2.485
November	10.0	63.08	3.140
December	5.3	32.44	1.545

The following table, by Dr. Smallwood, indicates the temperature of the year in the middle part of Canada, and shows the mean of 20 years' observations.

IV. MEANS AND EXTREMES OF TEMPERATURE, AND PERIODS AFFECTING VEGETATION.

Month of January	13°26
" February	13°21
" March	25°44
" April	40°12
" May	55°70
" June	62°11
" July	74°78
" August	61°21
" September	58°12
" October	46°04
" November	31°49
" December	13°80
Mean of the year	41°50
Highest temperature observed	100° 5
Lowest	–43° 6
Earliest frost of Autumn, August 18th.	
Latest frost of Spring, June 16th.	
Latest ploughing, December 10th.	
Earliest snow, October 10th.	
Latest snow, May 20th.	
Highest temperature of the ground at 18 inches in depth	67°
Lowest do do	32°
Number of days of rain	87
Number of days of snow	46
Number of fair days	232
Number of days of thunder and lightning	15
Amount of rain in inches	47.224
Amount of snow in inches	79.500

Another point of interest to the farmer is the comparative periods of vegetation in different places and seasons.

V. COMPARATIVE TABLE OF PERIODS OF VEGETATION.

Plants.	Lower Canada, by Dr. Smallwood.	New Brunswick, by Professor Johnston.	Scotland, by H. Stevens.
Barley sowed	15 to 16 May	10 May to 15 June	April and May.
reaped	15 to 16 Aug.	20 Aug. to 25 Sept.	
days in ground	92	96	
Spring Wheat			
sowed	1 to 8 May	15 April to 1 June	8 to 26 March.
reaped	1 to 8 Sept.	10 Aug. to 20 Sept.	26 Aug. to 30 Sept.
days in ground	123	110	153 to 186.
Oats sowed	1 to 8 May	April and May.	January.
reaped	10 August	Aug. and Sept.	
days in ground	97	110	
Indian Corn			
sowed	20 June	15 May to 1 June	
reaped	29 Sept.	1 Sept. to Oct. 2	
days in ground	101	117	
Buckwheat			
sowed	20 to 29 June	1 to 30 June	June.
reaped	18 Sept.	1 to 25 Sept.	September.
days in ground	90	93	120.
Potatoes planted	20 to 25 May	10 April to 20 June	March & April.
dug	29 Sept.	Sept. and Oct.	October.
days in ground	131	150	150.

This table might be greatly extended by adding the periods of other cultivated plants. Its value is limited by the great local variety that occurs in these respects, owing to differences of soil, drainage, exposure, and elevation. One object in presenting it here is to indicate to farmers the utility of carefully noting these points for each year, in connection with the results of more or less early sowing, the character of the season, the effects of manures, and of different methods of tillage and of drainage.

II. DIRECTIONS FOR PERFORMING EXPERIMENTS ILLUSTRATIVE OF THE SUBJECT.

A teacher who has himself studied the elements of chemistry, can readily illustrate its applications to agriculture by experiments which will greatly add to the interest of the subject. Cheap sets of apparatus for this purpose are prepared by the manufacturers of chemical apparatus, and are very convenient; but with a little ingenuity and practice, all that is necessary can be done with a few phials and other ordinary vessels, and the chemicals which can be procured in any druggist's shop. The following directions are taken with slight modifications from Johnston's Catechism of Agricultural Chemistry. They relate to the illustration of the elements and food of plants, as stated in chapters 4th and 5th of this manual.

1. Oxygen.

The least troublesome mode of preparing oxygen, is to rub together in a mortar equal weights of chlorate of potash and black oxide of manganese, to put the mixture into a common Florence flask, and apply the spirit lamp. With the aid of a glass tube, bent by means of the spirit lamp, and adapted by means of a cork to the mouth of the flask, the gas may be collected over water in wide-mouthed phials or receivers. Half a teacupful of the mixture will be found sufficient to fill several small receivers with the gas. For details of the manipulation see section 8th below.

Oxygen gas may also be prepared by mixing sulphuric acid (*oil of vitriol,*) with black oxide of manganese in fine powder, in a retort, and applying the heat of a lamp; or by rubbing together in a mortar equal weights of oxide of copper and chlorate of potash, putting the mixture into a small retort, and applying the lamp as before. The last is the quickest method of the three.

The properties of oxygen may be very well shown with-

out the necessity of collecting the gas. Thus, the mixture of chlorate of potash and oxide of copper above described, may be put into an open tube, and the flame of a lamp applied for a few minutes; when a bit of red hot charcoal, or a match, of which a spark is still red at the extremity, will burn brilliantly if introduced.

2. Hydrogen.

Fig. 1.

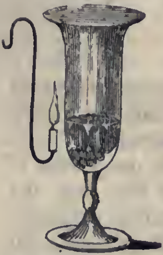


Fig. 2.

Take a beer or champagne glass (Fig. 1), put into it some pieces of zinc or iron filings, and pour over them a small quantity of oil of vitriol (sulphuric acid) diluted with twice its bulk of water, and cover the glass for a few minutes. On putting in a lighted taper, an explosion will take place. The teacher may repeat the same experiment in a phial, into the cork of which he has introduced a common gas jet (Fig. 2). After a short time, when the hydrogen gas produced has driven out all the common air from the bottle, a light may be applied to the jet, when the gas will take fire and burn. The cork and jet may now be taken out of the bottle, and a lighted taper introduced into it, when the taper will be extinguished, while the gas itself will take fire and burn at the mouth of the bottle. Lastly, if the teacher possesses a small balloon, he may fill it with the gas by attaching it to the mouth of the bottle, and may thus show that the gas is so light that it will carry heavy bodies up with it through the air.

3. Nitrogen.

Place a piece of phosphorus in a small tin cup, and cause it to float in water, in a shallow basin or deep plate; ignite

the phosphorus and insert over it a receiver or wide-mouthed bottle with its mouth below the surface of the water; the burning phosphorus consumes the oxygen of the enclosed air, and forms white fumes of phosphoric acid, which are rapidly absorbed by the water. At the close of the operation, the water will be found to have risen and filled one-fifth of the vessel, and the remaining gas will be nitrogen. This experiment shows very prettily the composition of atmospheric air, and affords, with little trouble, a supply of nitrogen for showing its properties.

4. Chlorine.

This gas is readily prepared by pouring muriatic acid on black oxide of manganese in a retort, and applying a gentle heat. It should be collected over hot water.

An easier mode of showing some of the properties of this gas, is to put a little dry *chloride of lime* into the bottom of a tall glass, and pour upon it strong sulphuric acid. Chlorine gas will be given off, and will gradually fill the lower part of the glass, and the boys may then be made to smell it, and it may be shown,—1st. That a taper burns in it with a smoky flame and is soon extinguished. 2nd. That it is much heavier than common air, by pouring it from one glass to another, or upon the flame of a candle. 3rd. That phosphorus takes fire in it of its own accord. 4th. That it gives a red color to a solution of iodide of potassium when poured upon its surface, or a purple color if a little dissolved starch be previously mixed with the solution of the iodide. 5th. That the color of red cabbage or red tape is discharged by it. It is not absolutely necessary for the teacher to make all these experiments, but they are very simple; and they are likely so to impress the knowledge of this gas, chlorine, upon the mind of the pupil, that he will never forget it.

A very neat method is to put the materials into a flask with bent tube, as for the preparation of oxygen; pass the end of the tube to the bottom of a tall wide-mouthed phial or jar, and the chlorine, being heavier than air, will gra-

dually fill the vessel, in which the experiments mentioned may be readily performed. The operator should carefully avoid inhaling any of the gas, and the flask should be removed from the room as soon as the experiments are performed.

5. Carbonic Acid.

The teacher may prepare carbonic acid gas, by pouring dilute muriatic acid upon bits of limestone, or of the common soda of the shops, in a tall covered beer glass. He can show that a burning taper is extinguished by this gas; but that it does not, like hydrogen, take fire itself;—that it is so heavy that it may be poured from one glass to another; and that when poured from a large tumbler a common candle may be put out by it.

6. Phosphoric Acid.

If the teacher can obtain a piece of phosphorus, he may show how it burns with *white fumes* in the air, and may collect these white fumes—which are phosphoric acid—by holding over them a cold glass or metal plate, or he may simply burn the phosphorus in a little cup under a tumbler.

A still simpler way of making his pupils acquainted with phosphorus and phosphoric acid, is to take a common lucifer match, of the variety that kindles without explosion, and to rub the end of it on the sand-paper so gently as not to kindle it. If it be now brought near the nose the smell of phosphorus will be perceived. If it be again rubbed so as to take fire, it will burn with a white flame, and will for a short time give a white smoke. *This white smoke is phosphoric acid.*

7. Properties of Acids and Alkalies.

Prepare a dilute solution of sulphuric acid (oil of vitriol), or muriatic acid. By tasting a rod dipped in it, the

sour taste characteristic of acids will be perceived. By pouring a little of it into an infusion of red cabbage or of violets or of litmus, this will be reddened. By pouring it upon common carbonate of soda the carbonic acid of that substance will be expelled, and a sulphate or chloride will be the result, which may be seen in a crystalline state, as a salt, by evaporating it to dryness.

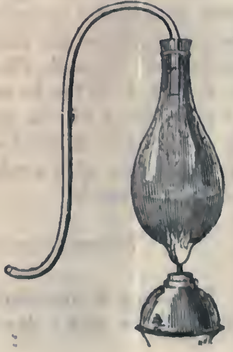
Make a strong solution of potash or soda, and add this to the cabbage infusion which has been reddened by the acid, and its blue color will be restored, and by adding more it will become green. Similar changes of color are produced by acids and alkalies in the juice of beets or blueberries or of the purple dahlia.

8. Modes of Preparing and Collecting Gases.

Figure 1 shows how this may be done over water, with a flask or bottle and a bent tube (*a*), a flat basin (*b*) for a cistern, and a tumbler or wide mouthed phial (*c*) for a receiver. This last must be filled with water and inverted, and a little shelf of bent iron or tin may be placed in the water for it to rest on. When full, a plate or saucer may be placed under it, and it may stand aside till others are filled, taking care to leave a little water in the saucer to prevent the escape of the gas.

Fig. 3.

Fig. 4.



When heat must be applied, as in preparing oxygen, a flask which will endure this without cracking must be used, and a lamp applied as in Fig. 5. A stand to support the flask may be made with an iron rod fixed upright in a block of wood, and furnished with rings of wire having the ends twisted round the rod spirally.

9. Soluble Organic Matters in the Soil.

An interesting experiment in illustration of these is the following:—Take a small quantity of vegetable mould, place it in a flask with some water and a little potash or soda, and boil it for some time. When cool, filter it through blotting paper placed in a funnel, and a clear brown solution will be obtained, illustrating the solution of the vegetable acids of the soil (humic and ulmic acids) by the aid of an alkali, and also the character of the dark colored waters of bogs and swamps. Then to a portion of this solution add a little hydrochloric acid. This will combine with the alkali, taking it from the organic acid; and this last becoming again insoluble will float up to the top as a grayish scum, which, if collected and dried, may be regarded as pure humus or vegetable mould.

10. Chemical Analysis.

The analysis of soils is a tedious and difficult operation, requiring, on the part of the operator, not only a large acquaintance with chemistry, but much skill and practice, pure chemical tests, and somewhat expensive apparatus. Neither the farmer nor the teacher can therefore, in ordinary circumstances, be an analytical chemist. Since, however, it may sometimes be desirable to ascertain in a rude way the general composition of soils and manures, I give here the following simple processes, principally from Professor Norton:

The mechanical texture of a soil is ascertained by simply washing with water. Dry the soil; weigh a portion, say a pound or half-pound, boil in water, and stir thoroughly.

The sand will settle first, and when it is at the bottom, the liquid above, holding the clay, &c., in suspension, may be poured off into another vessel. A few repetitions of this will leave nothing but clean sand and gravel, if the soil contain any. This may be dried and weighed, and the quantity will indicate to which of the classes already referred to (loams, clays, &c.,) the soil belongs. An examination of the small stones and coarser grains of sand, to ascertain whether these be granite, trap, sandstone, &c., may be useful in forming an estimate of the qualities of the soil.

The following course may be adopted, in case more information is desired, regarding the especial constituents of a soil:

1. Take a weighed half-pound or pound of the soil, and boil it in water for some hours: rain water is purest. Then pour it upon a filter of coarse porous paper, of the kind that druggists use for their filtrations. The mode of managing this operation may be seen in any druggist's shop. If the liquid does not come through clear at first, it must be refiltered till it is quite clear. The solution thus obtained is evaporated to dryness, and the solid residue burned. It will blacken at first, by the burning of its organic matter, but afterwards will become white again.

a. It may now be weighed on a small apothecaries' balance, and the weight gives the per centage of inorganic matter soluble in water, that exists in the soil.

b. This portion consists, in many soils, for the most part of sulphates or carbonates of potash and soda. There is also commonly present some chloride of sodium, or common salt.

These are all valuable constituents of a soil; and hence, when an experiment of this kind shows such soluble matter to abound, it may be inferred that the soil is well supplied with an important portion of its requisite substances.

c. The part soluble in water is commonly not large: it amounts to not more than from one to three per cent. in many excellent soils.

2. Take another weighed portion of soil, or the same which has already been boiled in water, and heat it with

some muriatic acid (hydrochloric acid), diluted by two or three times its bulk of water. After standing a few hours, put this also upon a filter, and wash the acid liquid through.

a. Wash the residue upon the filter with successive portions of clear water, until it no longer tastes acid; it may then be burned until all of the organic part is consumed, and weighed when it is cool. This weight gives the per centage of insoluble silicious matter in the soil.

b. To the filtered acid solution is first added ammonia (common aqua ammoniæ,) till it is no longer acid but alkaline; a flocculent precipitate then immediately falls, being iron and alumina. If it is of a deep red color, then iron predominates; and the contrary if it is nearly white. If the precipitate has a whitish green color, and reddens when exposed to the air, then the soil contains the protoxide of iron, in place of the peroxide. The first, it will be remembered, was spoken of as injurious to plants. It is for this reason important to know which oxide is present.

If it is shown by the above test to be the protoxide, the solution must be boiled again with an addition of a little nitric acid: this will convert all of the iron into protoxide, and it will thus remain upon the filter; the protoxide would have been partially washed through. Another filtering is now necessary. This should be done as soon as the precipitate has settled, and while the liquid is warm, so that it may filter more rapidly. The whole operation should be done in the shortest practicable time, and the liquid covered as far as possible from access of air.

From the apparent quantity of the iron and alumina, as weighed after burning, may be judged with tolerable accuracy the proportion present in the soil.

c. If the soil contained much lime, effervescence would have been seen at first, when the acid was added; this is supposing the lime contained to be carbonate, or in combination with carbonic acid, that being the most common form. If it is not present as carbonate, or if this is in so small quantity as not to show any action with acid, there are still means for its easy and certain detection. To the solution previously rendered alkaline by ammonia, and

already filtered to separate iron and alumina, is to be added a little common oxalic acid. If there be even the smallest weighable quantity of lime present, a white powdery precipitate will begin to fall; from the quantity of this may be estimated roughly the proportion of lime in the soil.

All of the above important points, it will be noticed, may be determined without any necessity for expensive materials or apparatus, by a person of ordinary intelligence. Easy as those things seem, however, in the description, so many difficulties will be found in practice, as will give the operator some conception of the care and study involved in a complete and detailed analysis; one by which it is intended to ensure the greatest possible degree of accuracy.

I have not mentioned any tests for the presence of phosphoric acid, and other of the less abundant substances; because their detection and separation are so difficult, that the inexperienced beginner would only run into every description of error while looking for them.

It is not a hard matter for the farmer to arrive at the probable value of a marl, with quite a tolerable degree of accuracy. A weighed portion must be taken, and diluted muriatic acid added from time to time, until all effervescence has ceased. The mixture is then boiled, or at least well heated, and thrown upon a filter. The insoluble residue which remains upon the filter, must be washed clean from acid, dried and weighed; this is chiefly silica. Its weight, subtracted from the original weight taken, will, in most cases, give nearly the amount of carbonate of lime that has been dissolved out by the acid. Small quantities of other substances have been dissolved at the same time, which have been mentioned in a previous chapter, as important to the value of the marl; but they are only to be separated by an instructed chemist.

The presence of gypsum in a marl, &c., may be ascertained in the following manner: Stir a portion of the substance in water, and allow it to stand for a few hours. Then filter off the water, and add a few drops of solution of nitrate of baryta. If gypsum be present, a white powder will fall to the bottom, and the quantity of gypsum present may be estimated from its amount.

III. Rotation of Crops for Canada.

Under this head I think that an important benefit will be conferred by republishing the substance of the recommendations published many years ago by Mr. William Boa, of St. Laurent, and which have been of the utmost service to the cause of agricultural improvement throughout British America.

1. *Requisites of a Good System.*

1st. It ought to be economical, and not require more capital than the actual system, or rather than the present absence of system, requires. It is undoubtedly of great advantage to apply capital to the land, but this advantage is in general beyond the reach of our farmers, as their means are not sufficient.

2nd. It ought to restore fertility to the soil, and maintain it by the products of the land itself. Manures got from other quarters than the farm itself, are always expensive, and, at a distance from town, are often not to be had at all.

3d. It ought to be simple and of easy application.

4th. Finally, it ought to have experience clearly in its favor.

2. *Rotation of Crops.*

There are two sorts of reasons in favor of the plan of rotation of crops.

1st. Because different plants draw from the soil different sorts of food, so that one plant will grow freely in a soil which is worn-out as regards another.

2nd. Because the crops being various, the occasional failure of one is not so much felt, seeing that the others furnish subsistence sufficiently without it.

The cultivation of a fair proportion of all the varieties of crops which Providence permits to grow readily, ought therefore to be considered as the best means of averting a famine; and what intelligent farmer, with the case of Canada and Ireland before him, would wish to be limited to the culture of wheat and potatoes only.

3. *Plan of the Rotation.*

Divide the arable portion of the farm, whatever may be its size, into six parts, as equal as possible, with a direct communication from the barn-yard to each field, and from one field to the other,

so that the cattle may pass from one to the other when required. This division into six fields, may require on most farms new fencing, and it will be proper, beforehand, to see how this can be done with the least possible expense. I shall now suppose the farm prepared to receive the application of this system, and that is the one which I have found the best for even the poorest settler.

1st. Root crops, such as potatoes, carrots, beets, parsnips, &c., [turnips and also flax] and in cases where the land is not sufficiently open for a crop of this kind, the field must be left in fallow.

2d. Crop of Wheat or Barley.
3d. Crop of Hay.
4th. Pasture.
5th. Pasture.
6th. Crop of Oats or Peas.

In beginning the application of this system, that field of the series which is in best condition for a Root crop, should be called field	A
The best for Wheat or Barley	B
That which is actually in Hay.....................	C
The Pasture fields..............................	D & E
That which is best for Oats or Peas................	F

Each field for the first year ought to be appropriated to the crops above mentioned, and after the fashion now in use among the farmers of Lower Canada, except in the case of field A. By this plan they will at all events still get as much from their five fields as they get at present.

The culture of field A and of crop No. 1, come up together for the first year, and ought to be the object of special attention, as this is, in fact, the key to the whole system; for the good culture of this field has for its object, and ought to have for its effect, not only a good crop for the first year, but also to improve the land for the five other years of this Rotation of Crops.

In the following year, the cultivation of the different crops will be according to the following order:

Crop	No. 2	in the	field	A
Do.	" 3		"	B
Do.	" 4		"	C
Do.	" 5		"	D
Do.	" 6		"	E
Do.	" 1		"	F

and so on, changing each year until the seventh, when crop No. 1 will come back to field A, and the whole will then be in a good state of fertility, aud free from weeds. The above system has been proved to be capable of restoring old land, and extirpating all weeds.

In order to render the thing more simple and easy of comprehen-

sion, I shall suppose myself to be again obliged to begin with a worn-out farm in the autumn. The first thing that I should do, would be to divide the land into six fields, by proper fences, to prevent the cattle going from one field to the other; and I would then take for field A, that which appeared best for green crops or root crops; I would collect all the manure which I could find in or out of the barns, I would take out the flooring of the cow-house, stable and piggery, and I would take out as much of the soil underneath as I could get, for this soil is the essence of manure, one load of it being as good as four or five loads of common dung. The portion thus removed, ought to be replaced by an equal quantity of ordinary soil, or, if it be possible, of bog earth, which might be removed when necessary afterwards.

The dung and other manure thus collected, should be placed on the field A in September, or the beginning of October, spread with care (as far as it will go), and covered up in a shallow furrow. Manure aids the decomposition of straw and the weeds of the soil, and frees it from these plants, which thus help to keep the soluble portion of the manure, until its juices become necessary for the crops of the succeeding years. The greater variety there is in the crops of this field, the better it will be, provided the soil is suitable for them. Thus this field ought, as nearly as possible, to look like a kitchen garden.

4. *Crop 1st.—Root or Green Crop.*

Under the actual circumstances of the country, I would particularly call the attention of farmers to the cultivation of the carrot as being one well adapted to our soil and climate.

The land which has been manured in the fall, as above described, ought to be ploughed at least twice in the spring, the one furrow across the other, and both as deep as possible. It is then to be harrowed until it is properly mellow. You then make with the plough two furrows, distant two feet, or two feet three inches from each other, taking care to raise the soil as much as possible between each. You pass the roller over this ploughed portion, and then with the corner of a hoe, make a small furrow or drill along the top of the rows: drop the seed into this furrow, and pass the roller over it again: this last operation will cover the seed sufficiently.

If you can get a seed-sower, that will simplify matters considerably. A roller is essential in the culture of root crops which spring from small seeds, but it can be readily got by all farmers. A log of twenty inches diameter, and five feet long, with a pole fixed at each end, will do the business admirably.

Carrot seeds (and you may say the same of the other seeds), ought to be soaked in rain, or soft water, until they are about to sprout, and then rolled in quick-lime until the grains are dry

enough not to stick to each other. When there is no lime, wood ashes will do as well. A pound of seed, if it be good (and you ought always to try it before sowing), will be sufficient for one acre of land. By the above plan, the young plant will come up before the weeds, so that it will be easy to distinguish the rows of carrots before the weeds appear: this renders the cleaning comparatively easy, since it may be done (except the thinning) by means of a cultivator. This cultivator is an instrument which every settler ought to have, and which, like those already mentioned, is extremely simple in its construction. It is made of three bars of wood joined in front, and separated behind, according to the width of the furrows which you wish to clean. This instrument, called the horse-hoe or drill-harrow, or cultivator, is drawn by one horse, and has handles to it like a plough, only lighter. A man or a boy may guide it, so as not to touch the rows of carrots or other crops, but only to raise the soil to a greater or less depth, at pleasure. As soon as the weeds appear, you draw this harrow between the rows, so as to bring the soil as close as possible to the young carrots, but without touching or covering them. This process will keep the plants sufficiently clean until the time for thinning them and leaving them four or five inches apart from one another; soon afterwards you may plough between the rows thus harrowed and raised. These operations do good to the plant, by permitting air and moisture to have access, and by facilitating evaporation. My plan for gathering the carrots in autumn, is to pass the plough along the right side of the plants as close as possible, without injuring them: this frees them on one side, and the stem is strong enough to allow us to haul up the roots by it afterwards.

This method of culture requires a good deal of labor, but the return is more than enough to recompense the farmer.

When we consider the large amount of nutritive matter contained in this root, and its general application to all the living things on a farm, its culture cannot be too strongly recommended, besides it is relished by all animals, especially by working horses, to which it may be given instead of Oats.

I have dwelt particularly upon the culture of the Carrot, because the same method applies to the culture of all the root crops, which can be advantageously grown in this climate, such as Parsnips, Beets, Mangels and Turnips.

Parsnips will grow in a close soil, almost in clay, and do not require cellars, since they will remain uninjured all winter in the ground. In this case you will have them in the spring, affording a new and succulent food, at a time when it is most necessary. Every animal will eat parsnips with relish, and cows fed upon them yield a very rich milk.

Beets and Mangels have the same value as a crop, and as food

for milk cattle; but I do not consider them to be so good for fattening cttle.

[In spring, all the manure made during the past winter should be carted to the field, placed in a heap, and twice turned. All bones should be gathered and broken up with a hammer; all coal and wood ashes, scrapings of sewers, the dung from the fowl house, and the contents of the privy, should be collected and made into a compost, with dry loam or bog earth.

The above manure may be used for that portion of the field devoted to cabbage, potatoes, and turnips. It should be put in the bottom of the drill on which the above are to be planted or sown.

When the ground is properly ploughed and harrowed, and a sufficient quantity of sound seed sown,—say, at least, four pounds to the acre,—the turnip crop is as certain as any other.

The sowing of turnip seed should be commenced early in June, and may be continued up to 20th July. If the fly takes the first sowing, a second will be likely to succeed.

The turnips, when well up, and getting strong, should be thinned out to a foot apart, and the hoe and cultivator passed through them at least twice before they meet in the drills.]

If the land is too heavy for root crops, beans and green peas will suit for No. 1, taking care to sow them in drills, and to prepare the land as above described for root crops.

If it be thought absolutely necessary to summer-fallow,—that is, to plough without sowing,—which only happens when the soil is so hard and heavy that it cannot be pulverized in any other way, you ought not to spread the manure on the land in the preceding fall; but plough the land, and ridge and furrow it with as much care as for a crop. You need not touch it again before the month of June; when you must plough it again, and harrow it, so as to render it even, and destroy the roots of the weeds. You may then draw the furrows in a straight line, giving them a uniform breadth, and so as to facilitate drainage. About the middle of July, you must plough it again, and sow it with plenty of buckwheat. At the end of September, plough it again, having previously spread it with dung. In this case, the buckwheat is ploughed under with the manure, and serves greatly to increase the latter. The land thus prepared, ought to be sown with wheat in the ensuing spring, and you may add a little timothy and clover. A bushel of timothy will suffice for four or five acres, and three or four pounds of clover to each acre.

5. *Succeeding Crops of the Rotation.*

I have now done all that I can for field A. I have weeded and manured it as well as I can; and after having taken the crop of roots, and the crop of wheat or barley, next year, I leave

this field to rest until the other fields have been improved in the same way, and according to the method above described. When this shall have been effected,—that is to say, in the space of six years,—the worst will be over, and the battle may be considered as gained. The fields will then be in a clean and fertile condition, and their value will consequently be greatly increased. The farm of 70 or 80 acres, which at first only sustained three or four miserable cows, and perhaps no more than an equal number of sickly sheep, will be capable in less than ten years, of furnishing an abundant subsistence for ten or twelve cattle, and other stock in the same proportion.

One of the great advantages of this system of rotation of crops is, that the pastures, which in summer furnish summer-feed for the stock, are in due proportion to the quantity of roots and hay destined to winter-feed them, and in due proportion to the straw which the grain-crops yield for their bedding. I will observe here, that farmers—except those who live near towns, where they can easily procure manures—ought never to sell a single load of their hay, straw, or roots; since the whole ought to be consumed on the farm, with the view of procuring a sufficiency of manure therefrom, whereby the fertility of the soil is to be sustained. But if the farmer is not to sell hay, or straw, or roots, what is he to sell? I answer, the third of the land being, under this system, appropriated to grain crops, he will always be able to sell a large part of them. The half of the farm being in hay and pasture, will allow it to produce a large quantity of butter, cheese, butchers' meat and wool; and to sell a considerable part of these, after having supplied the wants of the family. It may be said, that six years is a long time to wait for the renovation of the whole farm, but I will reply, that I know of no other means by which it may be done in less time, from its own resources; and it is worthy of observation, that the land is improving every year. The produce is larger, even for the first year, under this system than it is under the present method of culture; and, from year to year, the land is improving, field by field, and is producing more and more, so as to pay the farmer better than it does at present, and to recompense him doubly afterwards, when the whole shall have been improved under a system of rotation.

It may be objected, that two years of pasture is a long time of rest for the land; but you will observe, that the land does not remain unproductive during this period of repose. This plan not only contributes to re-establish the almost exhausted fertility of the soil, but it is also the best means of furnishing the farmer with the first necessaries of life, and the articles which, so to speak, will most readily find an outlet in our markets,—such as beef, lard, mutton, butter, cheese, wool, and other products already named.

Manures are of the first importance to the farmer, and he must do everything in his power to increase their amount. The system here proposed, is calculated so as to increase the quantity of manure in proportion as the soil becomes improved. As already said the farmer ought not to sell a particle of his hay or straw, because these are the principal materials for manure; and, consequently, it is infinitely worse to sell the manure itself. The manure, thus economized, will suffice each year for the field which is to receive the root crop (No. 1).

After the crop of oats (No. 6), the land is not yet exhausted, and might even yield another grain crop. It is better, however, to preserve this fertility when acquired, than to be obliged to bring it back.

In this short treatise, it is impossible for me to mention one hundredth part of the means which we have of increasing our stock of manure. I shall content myself with alluding to the rich deposits of bog-mould which we possess, and the limestone, which can be had every where. The very weeds, which are the curse of our fields, may be converted into good manure.

6. *Farther results of Experience.*

Mr. Boa has kindly favored the writer with some further results of his experience in rotation farming, and especially in relation to the relative effects of different green crops. His results in this respect quite accord with what might have been inferred from the composition of the ashes of these plants, and point to the proper manures to counteract the special effects produced on the soil by certain given crops. The following is an extract:—

I have said that the culture of crop No. 1 in the field is the key to the whole system. Now, as I have always considered the cultivation of this field as rather a means than an end, I have paid particular attention to the effect the several green crops have upon the following grain crop, say wheat or barley. I have found mangel wurzel to be the worst of all the green crops cultivated for the grain crop. The seed comes up as well after it as any of the other crops, but as soon as the roots begin to strike, and the plants begin to tiller, it evidently falls behind and keeps behind. The crop is always thinner; is about eight days later in ripening than on potato-land; the straw is always soft, of a dull color, and affected with rust.* Although this is a bad crop to precede wheat or barley, I am not prepared to say that it is a great exhauster of the soil; for in some experiments I have made, I have found the clover crop which followed

* This is probably an effect of the large removal of potash by mangel wurzel. Wood ashes applied with the wheat might be a remedy.

it, to be as much superior as the grain crop was inferior. Turnips have much the same effect as mangels, when carried off the land, which is generally the case here.

The grain crop, especially wheat, does better after horse-beans than any other crop, if the beans are sown in drills, and manured with the same quantity of stable manure as the other green crops; but clover seeds do not take well, and do not thrive after them; but timothy grass does well. Potatoes, carrots, and Indian corn are nearly alike favorable to grain and grass. I find carrots thrive best when manured with compost containing a large proportion of swamp muck. They appear to detest lime. I have sown them twice on a piece of land that got a strong dose of lime some years ago, and got very poor, scrubby crops of carrots. Last spring I sowed hemp on the same piece of ground, without giving it any manure, and the hemp grew over twelve feet high. It appears to feed and thrive well on what is poison to the carrot. I have introduced hemp as a crop for the last two years. I know now from the trials made with it, that this country can produce as good hemp, if properly managed, as any other country; and that it will pay the farmer better than wheat or barley, as things go at present. A good crop will yield over half a ton of fibre per acre, and fifteen or sixteen bushels of seed. I sold the fibre, of my crop of 1862, at eight cents per pound, and have been offered five cents per pound for the seed of the crop of 1863. The place of hemp in the rotation, should be as a green crop, as it is an extirpator of weeds; but it must be harvested before the seed is ripe, or it will leave its seed on the ground, and prove a weed itself in the next crop, if wheat or barley. When cut before ripe, the fibre is much finer that when it has ripened its seed. When seed is intended, it should be sown in drills or narrow beds, so that the male plants can be pulled as soon as they have shed their pollen, without trampling or breaking down the female plants, which must be left standing to ripen the seed.

Mr. Boa also states his experience in the case of the wheat midge and potato blight, which accords very closely with the views given above under those heads, and would have been inserted in confirmation of these views had it arrived in time. He further refers to the results obtained in rotation farming since the publication of his pamphlet; and shows that, when fairly tried, it has produced the best effects. He remarks, however, that it must be adapted to different soils, as the number of years covered by the rotation may be varied from six to twelve, under different circumstances.

THE END.